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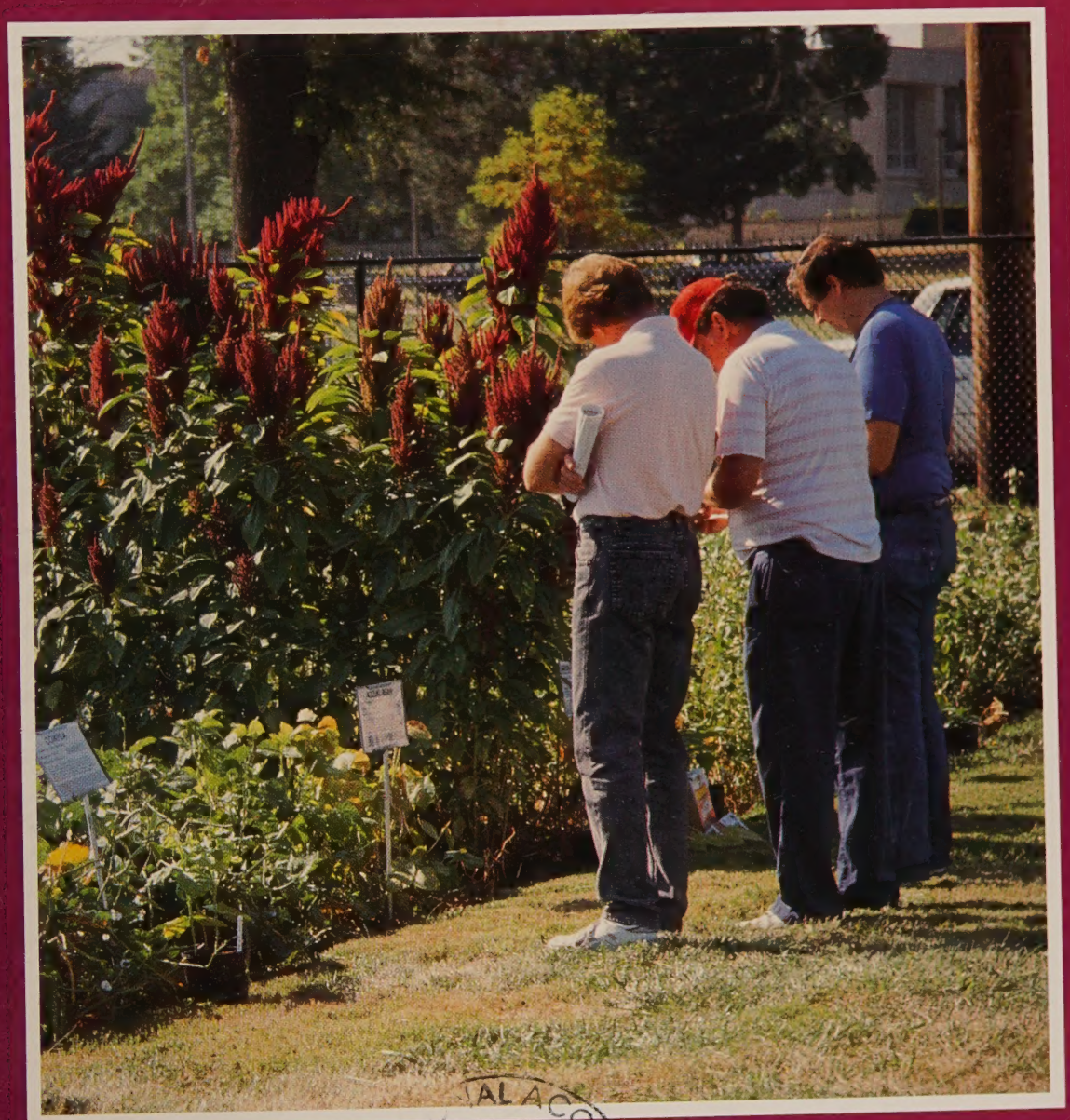

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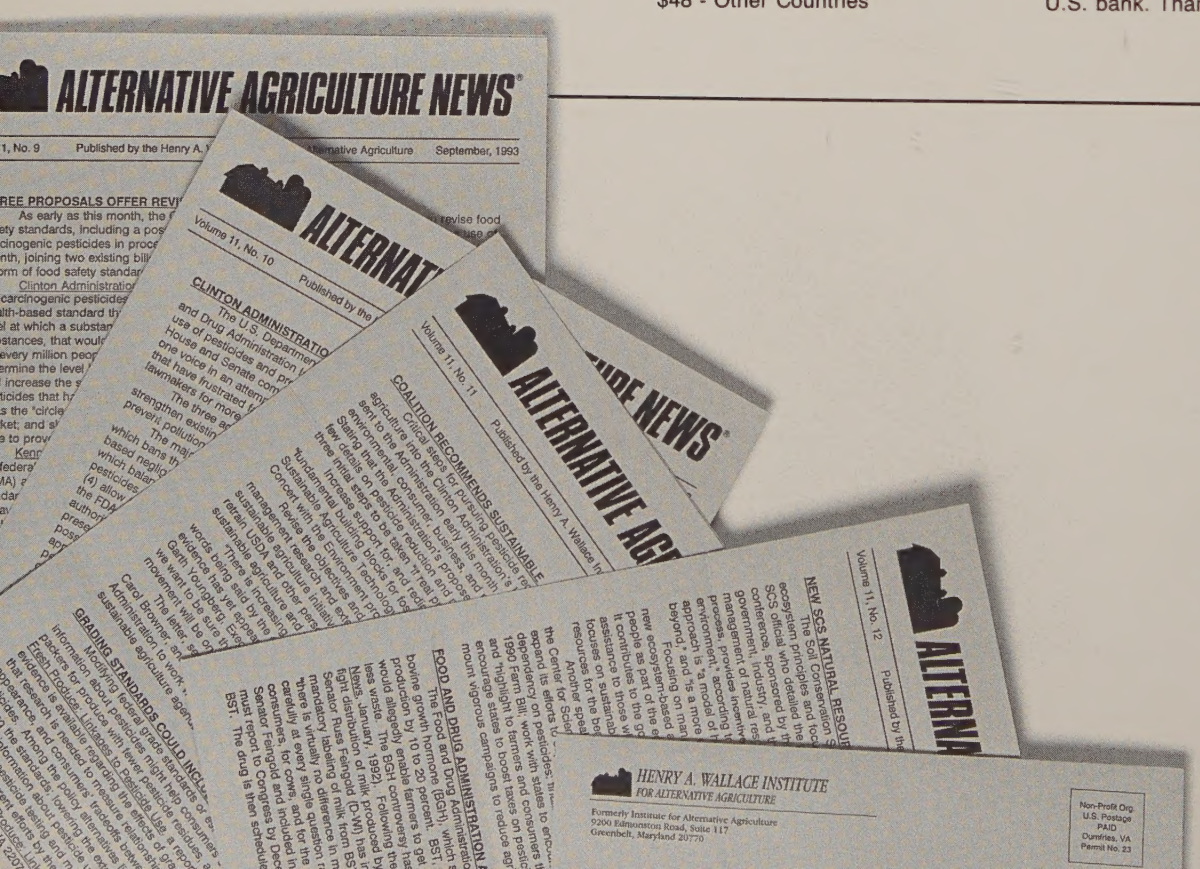

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Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover shows a small group of individuals observing amaranth at the mid-flowering stage during a tour of the alternative crops research and demonstration garden on the University of Missouri Campus, Columbia, MO. Photo provided by Robert L. Myers, Assistant Professor, Department of Agronomy, University of Missouri, Columbia, MO.

The transformation of Cuban agriculture after the cold war

Ivette Perfecto

Abstract. *Cuba's agriculture after the 1959 revolution had been based on large-scale, capital intensive monoculture, which made Cuba heavily dependent on the socialist bloc for subsidized agrichemical inputs and for set prices of agricultural exports. However, with the collapse of the Soviet Union and its Eastern European allies in 1989-90, Cuba's inputs of fertilizer, pesticides, and petroleum dropped by more than half. Cuba responded with a dramatic shift in its agricultural development model that featured appropriate technology, alternative organization of labor, alternative planning, and environmental preservation. Cuban pest control efforts now focus on biological control and on enhanced monitoring and diagnostic techniques. Soil management emphasizes biofertilizers and vermiculture. Minimum tillage and crop rotation are frequent practices among Cuba's independent farmers, agricultural cooperatives, and state farms. The transition to low-input agriculture has decreased the exodus of people from rural areas to cities, and has lead to establishment of labor camps with volunteer labor and long-term programs for rebuilding rural communities. To address the loss of important food imports while ensuring environmental conservation, agricultural planning now gives priority to crop rotations, city gardens, and introduction of food crops in sugar cane areas.*

Key words: Cuba, sustainable agriculture, low-input agriculture, biological control, biofertilizers, vermiculture, sugar cane

The defining feature of the postwar world, the cold war, ended in 1989. No other country in the Americas was more affected than Cuba. Its strong alliance with the Soviet Union was not only ideological, but also economic. The collapse of the Soviet Union and other socialist countries in Eastern Europe meant Cuba lost 73% of its total imports and a similar fraction (exact figure not available) of its exports (Lage, television interview; details of interviews, television programs, speeches, and other unpublished Cuban sources used in this article are given in the Appendix). In one year, Cuba found itself with less than 25% of its supply of fertilizers and pesticides, and with little fuel and no imported spare parts for tractors (Table 1). Although Cuba was already in transition toward a lower input agriculture (Levins, 1990), this transformation had met many barriers and was going slowly. The events of 1989 catalyzed that process. In what Cubans now call the "Special Period in Peacetime," a new and unique model of agricultural development is being invented. Its main characteristic is that agricultural inputs are being significantly reduced, and sometimes eliminated.

Because this was the first case in the world where a whole country turned to low-input agriculture, a group of agroecologists, farmers and other people interested in low-input agriculture organized a fact-finding mission to Cuba in November 1992. We spent 10 days in Cuba visiting farms, research stations and agricultural universities, and interviewing farmers, farm workers, agricultural extensionists, agricultural researchers, officials from the Cuban Ministry of Agriculture, and many Cubans not directly connected with the agricultural sector. (Members of the delegation are identified in the Appendix.) This article summarizes the findings from our trip and analyzes the ideological transformation that is an important part of the technological change.

The "Classical Model" of Cuban Agriculture

In the international socialist division of labor, Cuba's role was primarily to produce sugar, other agricultural commodities, and minerals, to be exported to socialist countries. In exchange, it imported agricultural inputs, petroleum, industrial equipment, supplies and foodstuffs from Eastern Europe and the Soviet Union (Pérez Marín and Muñoz Baños, 1991). Under very favorable terms of trade, sugar cane production went from 5 million to more than 8 million metric tons through a program of agricultural intensification and incorporation of lands that previously were used to produce other crops (Lage, television interview). By 1989, almost 30% of Cuba's agricultural land was in sugar cane, with sugar accounting for 75% of Cuban export earnings (Cuban Ministry of Agriculture, Appendix). Importation of cereals, powdered milk and other food products from Eastern Europe continued the transformation of Cuban food consumption patterns that had begun with Spanish colonialism and continued during the U.S. neocolonial dominance of the island at the turn of the century. Ironically, this international division of labor was based in the neoclassical concept of comparative advantage, which made it possible for Cuba to intensify agriculture significantly and specialize in certain crops while providing the population with a diverse and nutritious diet (Rosset and Benjamin, 1993).

In its first 30 years, the Cuban Revolution was committed to eliminating poverty, hunger and illiteracy and to distributing wealth equitably. By 1989, daily per capit

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Table 1. Cuban imports before and after the "Special Period."

Type	1989	1992	Decline (%)
	US$ million		
Food	1,011	600	41
Petroleum	2,598	850	67
Chemical Products	330	120	64
(Pesticides)	(80)	(30)	(62)
Raw Materials	307	60	80
Machinery/Equipment	5,531	350	94
Other Manufactured Goods	1,115	210	81
	10^6 Metric Ton		
Fertilizers	1.3	.3	77
Cereals and protein for animal feed	1.6	0.47	71
Petroleum	13.0	6.1	53

Sources: Preeg (1993); Lage (television interview).

intake of food energy and protein, which depended heavily on imported products, had increased to 2,898 cal and 77 g, respectively, among the highest in Latin America. Increased food consumption and other social and health programs resulted in one of the highest life expectancies (75 years) and the lowest child mortality rate (13.6 per 1000) in Latin America (World Health Organization, 1989). Illiteracy was almost eliminated; the adult literacy rate of 92.4% was close to that of the United States (95.7%). But many of these achievements were shaky, resting as they did on a dependent and unsustainable agriculture.

Cuban agriculture for those 30 years was based on what Cuban planners now call the "Classical Model of Agricultural Development" (Pérez Marín, interview). This model, which was based on regional specialization under the international socialist division of labor, shared many technical features with capitalist industrial agriculture. It centered on increasing production, although unlike industrial capitalist agriculture's goal of profit maximization, its goal is to increase the standard of living of the population. As in the U.S., Cuban agriculture experienced a dramatic increase in productivity. So, too, this increase was largely based on a shift toward mechanization and chemical inputs, which in Cuba's case were imported (Deere, 1992). As had happened in the U.S. in the 1940s and 1950s, tractors replaced animal power (oxen) in Cuba in the 1960s and 1970s, and much of the agricultural labor force moved to urban areas. Chemical fertilizers and pesticides became a cornerstone of Cuban agriculture and a symbol of its development (Vandermeer et al., 1993). By the late 1980s, Cuba was importing 48% of the fertilizers and 82% of the pesticides used for agricultural production (Deere, 1992). The consequences of such unsustainable agriculture led to even greater dependence on external markets, significant pressure on natural resources and the environment, and an accelerated rural exodus. Because of the devastating effects of toxic pesticides on the health of farmers, farm workers, and rural communities, pesticide use was minimized through strict regulations (Ovies, interview).

In contrast to this "Classical Model," since the breakup of the Soviet bloc, Cuba has followed the newer "Alternative Model." This model has four main components: appropriate technology, alternative organization of labor, alternative planning, and environmental preservation, each of which I discuss in turn in the following sections.

Appropriate Technology

The main components of appropriate technology are the minimization or elimination of agrichemical inputs and heavy machinery in a way that maintains productivity and minimizes health and environmental damage. To achieve this goal, Cuba has focused on ecological pest management, organic fertilizers and animal traction.

Pest control

Insects. The first significant steps toward a sustainable agriculture were made in the 1980s, when the Ministry of Agriculture adopted biological pest management as a national priority, after several biological control programs proved to be very successful (Levins, 1990). One such success was the use of the parasitic fly *Lixophaga diatraea* to control the sugar cane borer (*Diatraea saccharalis*). This fly was introduced in the 1930s, and by 1968 a program of mass rearing and release had begun. Today, *L. diatraea* is used on all production of sugar cane for planting and a large proportion of production for sugar. However, it is not new for most biocontrol specialists and does not represent a major breakthrough.

On the other hand, Cuba has pioneered the use and propagation of generalist ants to control insect pests in annual and semiperennial crops (Levins, 1990). The Chinese started using the ant *Oecophylla smaragdina* more than 200 years ago. However, although the ant colonies were managed, they never were propagated actively (Groff and Howard, 1924; Huang and Yang, 1987). Also, the ant was used to control insect pests in citrus, which are perennials. There is an untested assumption that because of their biological and ecological characteristics, ants would not be effective control agents in annual crops (Carroll and Risch, 1990).

Cuban researchers have proved this is not true, at least for the pantropical lion ant *Pheidole megacephala* (Castiñeiras et al., 1982). The idea of using this ant to control *Cylas formicarius*, the sweet potato borer, originated with local farmers who had witnessed the ant's voraciousness against the borer. The National Institute of Plant Pro-

tection Research (INSV) of the Ministry of Agriculture began researching the ant's potential in the early 1980s. Excellent results at the experimental level led to a pilot program on some farms, and finally to applying this control method to all sweet potato production in Pinar del Rio Province.

The management system includes establishment of *P. megacephala* reservoirs, either natural or artificial, where pesticide applications are prohibited. Reservoirs are mostly uncultivated areas with a high density of colonies of the ant. From there, ant colonies are transported to the sweet potato fields at the critical period for controlling *C. formicarius*.

A common but labor intensive method of transporting the ants is to encourage the colonies in the reservoirs to move their nests to cylindrical cuts of banana or plantain pseudostems, supplied with sugar or honey and protected from desiccation by banana leaves. After the pseudostems are colonized, they are transported to the sweet potato fields and placed at a previously determined density (9 colonies per ha), and the protecting leaves are removed to force colonies to move to the ground (Levins, 1990). Once there, *C. formicarius* becomes a regular prey item (Castiñeiras et al., 1982).

This method has provided almost complete control of the sweet potato borer in Pinar del Rio Province, and is now being used to control *Cosmopolites sordidus* (the black plantain weevil) in plantain production. For this pest, both *P. megacephala* and *Tetramorium guineense* are used, with an effectiveness of 60% to 70%. Because of the success of this program, all pesticide applications have been prohibited in areas where the program is in place. When the control of another pest becomes necessary, only biological insecticides are allowed. Cuba now has 14 centers for propagating ants for biological control.

Thanks to these and other previous developments in biological control, the "Special Period" did not represent a major shift in pest management strategy, but rather an expansion and intensification of what Cuba was doing already. One of its most impressive recent advancements in biological control has been to create local centers for the mass rearing and production of biological control agents (Thrupp and Pérez, 1989). Today Cuba has 218 Centers for the Reproduction of Entomopathogens and Entomophagous Agents (CREE) distributed in all the provinces (Dlott et al., 1993). These centers consist of simple facilities where artisanal techniques are combined with semi-industrial techniques, such as autoclaves and fermenters, to produce and distribute various biological control agents, such as parasitic wasps and bacterial and fungal pathogens of insects (Tables 2 and 3). Most raw materials and supplies used to prepare the cultivation me-

Table 2. Biological control agents mass reared in Cuba for the control of insect pests and nematodes.

Control Agent	Pest	Crop
Bacteria		
Bacillus thuringiensis	*Plutella xylostella*	cabbage
	Heliothis and *Spodoptera* spp.	tomato, pepper
	Spodoptera spp.	watercress
	Erinnyis ello	yucca
	Spodoptera spp.	sweet potato, potato
	Heliothis spp.	tobacco
	various lepidopterans	forest plantations
Pasteuria penetrans[1]	nematodes	
Fungi		
Beauveria bassiana	*Cosmopolites sordidus*	plantain
	Cylas formicarius	sweet potato
	Lissorhoptrus brevirostris	rice
	Pacneu (weevil)	citrus
	Diatraea saccharalis	sugar cane
Metarhizium anisopliae	*Mosis* spp.	forage
	Lissorhoptrus brevirostris	rice
	blue green weevil	citrus
	Cosmopolites sordidus	plantain
	Diatraea saccharalis	sugar cane
	Galleria mellonella	bee hives
Paecilomyces lilacinus	*Meliodogyne* spp. (nematodes)	guava, coffee
	Radopholus similis	plantain
Verticillium lecanii	*Bemisia tabaci*	tomato, pepper, bean, cucumber, potato
Parasitic Wasps		
Trichogramma spp.	*Mosis* spp.	forage
	Erinnyis ello	yucca
	Diatraea saccharalis	sugar cane
Parasitic Fly		
Lixophaga diatraea	*Diatraea saccharalis*	sugar cane
Ants		
Pheidole megacephala	*Cylas formicarius*	sweet potato
	Cosmopolites sordidus	plantain
Tetramorium guineense	*Cosmopolites sordidus*	plantain

[1] Still experimental

Sources: Bulletins of the National Institute of Plant Protection Research of the Ministry of Agriculture (Appendix); Thrupp and Pérez (1989).

dia are recycled from production farms and industry.

In 1991, these biological control agents saved the Cuban economy approximately US$15.6 million on about 815,000 ha. By 1992, the area treated had risen to 1 million ha, not including areas of sugar cane, citrus, and forestry plantations, most of which use very little insecticides (Ovies, interview).

Weeds. Controlling weeds and diseases ecologically is more difficult than controlling insects. Since 1990, Cuban researchers have intensified their efforts to develop integrated management of weeds and diseases, with good results.

The focus of the weed control program is to view weeds as a complex community of plants that interact with each other, with the crop, and with their environment. This approach uses data on such variables as the species composition in the seed bank, seed viability, and the ability of the crops being considered for planting the next season to compete against weeds. Through ecological modelling, the weed community for the next planting season can be predicted accurately, so that crops may be planted accordingly (Rosset and Benjamin, 1993). This method has been implemented on 16 state farms in all 14 provinces, but the success rate has not yet been reported. Other parts of the research agenda for weed management include crop rotations, selective use of herbicides, and the design of new tillage implements.

Diseases. For disease control, the focus has been on improving diagnosis and developing microbial antagonists that displace the pathogen but do not harm the crops (Ovies and Nalimova, interviews). Diagnosis techniques for plant diseases first were adapted from veterinary and health research in Cuba, and now include electron microscopy, ELISA tests, inmunofluorescence and dot blot tests (Shishkoff, 1993). These techniques are used for detecting quarantined pathogens, certifying seeds, and diagnosing diseases of field crops.

The use of microbial antagonists, although recent in Cuba, is showing great potential (Table 4). For example, in 1990 researchers at the INSV began searching for antagonists against a complex of root disease pathogens in tobacco (Shishkoff, 1993). They isolated and tested 25 colonies of *Trichoderma* fungi. After further evaluation they selected one isolate and began research on mass production of a *Trichoderma* inoculum. That isolate is now used in almost all tobacco seed production in Pinar del Rio Province, the main tobacco producing province in Cuba, and *Trichoderma* is being mass reared at some CREEs. As a result, tobacco farmers have eliminated the use of Ridomil® and methyl bromide for seed production in Pinar del Rio Province.

Table 3. Production of some biological control agents in the Cuban Centers for the Reproduction of Entomopathogens and Entomophagous Agents (CREEs) from 1985 to 1992.

Organism	1985	1988	1992
Bacillus thuringiensis (MT)	—	120	764
Beauveria bassiana (MT)	25	97	207
Verticillium lecanii (MT)	—	—	31
Trichogramma spp. (millions)	2	10	99
Pheidole megacephala (10^3 ha)[1]	7.9	8.3	15.3

[1] Land on which ant colonies were established.
Sources: Bulletins of the National Institute of Plant Protection Research of the Ministry of Agriculture (Appendix); Thrupp and Pérez (1989).

Table 4. Microbial antagonists used in Cuba for biological control of plant diseases.

Antagonist	Disease	Pathogen	Crop
Trichoderma sp.[1]	root disease	*Phytophthora nicotianae*	tobacco
	root disease	*Rhizoctonia solani*	tobacco
	root disease	*Fusarium* spp.	tobacco
	root disease	*Pythium* spp.	tobacco
	—	*Sclerotium rolfsi*	peanut, bean
Pseudomonas spp.[2]		soft rot bacteria	potato, banana

[1] It is not clear whether this is one species or a complex of several related species.
[2] Still experimental
Source: National Institute of Plant Protection Research of the Ministry of Agriculture (Appendix); Shishkoff (1993).

Pest monitoring. As a complement to the various biological and cultural controls of pests and diseases developed recently, Cuba has intensified its pest monitoring system, which today is probably the most comprehensive in the world. Pest monitoring plots are maintained at the 60 local research stations on representative sites planted with the important crops and varieties of the region. Detailed weather and pest data are collected regularly and sent for analysis to the corresponding provincial laboratory of the INSV. Farmers are warned of possible insect or disease outbreaks, although no specific recommendations are given. The method of control is determined largely by what is available in the region, mainly through the CREEs.

Many of these initiatives (except biological control of insect pests) are still at the stage of research or initial implementation. However, Dr. Jorge Ovies, Director of INSV, predicts that within the next five years they will be able to control most insect pests, weeds and diseases in agriculture through biological means.

Table 5. Agricultural soil classification in Cuba based on soil productivity.

Classification	% of agricultural land	Amount (10^3 ha)
High productivity	8.0	583
Productive	26.2	1,916
Low productivity	44.4	3,237
Very low productivity	21.4	1,553

Source: Ministry of Agriculture (Appendix).

Table 6. Production and application of vermicompost in Cuba, 1989-1992.

	1989	1990	1992
Number of vermiculture units	123	138	172
Area used for vermiculture (ha)	124	128	
Amount of vermicompost distributed (10^3 mT)	24	58	93
Animal manure used to produce (est.) (10^3 mT)	48	100	

Source: Ministry of Agriculture (Appendix); Gersper et al. (1993).

Cuban soils generally are poor. Two-thirds of all agricultural soils are classified as having low or very low productivity (Table 5). In the past, the focus for increasing agricultural production was on inorganic fertilizers, especially nitrogen and phosphorous. Today, Cuba has engaged in perhaps the most ambitious organic and biofertilizer program in the world (Delgado Diez, Calero, and Espinoza, interviews). This program includes techniques ranging from the old one of producing high quality earthworm humus out of bulky and low quality manure (vermiculture) to the industrial manufacturing of phosphorus-solubilizing bacteria, previously unknown on a commercial scale (Gersper et al., 1993).

Organic and biofertilizers. Vermiculture started in Cuba in the mid-1980s and was intensified in 1990 (Table 6). Vermicompost is produced from cow manure as the main source, but sheep and pig manure, sugar cane filter press cake, coffee pulp, and municipal organic garbage also are used. By 1992, Cuba was producing 93,000 metric tons of earthworm (California Red hybrid) humus at 172 vermicompost centers distributed among all provinces.

Commercial production of *Rhizobium* is now standard practice and has substituted for all nitrogen applications on leguminous crops. *Azotobacter,* a free-living nitrogen fixing bacteria, is the nitrogen source for nonlegume crops, including sugar cane (Añe, 1992). In 1992, 6 million liters of *Azotobacter* were applied to various crops (Lage, television interview), supplying half the nitrogen needs of nonlegumes. Perhaps because of a bias toward the temperate zone, most soil scientists assumed that free-living nitrogen-fixing bacteria were insignificant sources of nitrogen, and that the technology for producing them commercially was too difficult. However, recent studies in Egypt (El-Gamal, 1992) and India (Pandey and Shende, 1991; Reddy et al., 1991) suggest the potential of *Azotobacter* for use in sorghum, wheat and *Sesbania sesban*. Cuban researchers argue that these bacteria may be more significant in tropical than in temperate soils, and that Cuba has overcome the technical problems related to large-scale production. This has made Cuba the only country to use *Azotobacter* on a massive scale to replace nitrogen fertilizers, which largely became unavailable to Cuba in 1989.

Another biofertilizer, phosphorus-solubilizing bacteria, is an interesting novelty. Bacteria of the genus *Bacillus* are now used in Cuba on ultisols and oxisols. These soils are high in aluminum and iron oxides, which combine with phosphates to form insoluble complexes. This makes phosphorus a limiting nutrient in many of these soils, although it is abundant in the soil. The bacteria solubilize the phosphates, making them available for plant uptake. Although this biofertilizer is still at the developmental stage, it is now being tested on some production farms.

Also under intensive investigation is production of vesicular arbuscular mycorrhizal (VAM), symbiotic fungi that form associations in the roots of many plants and increase uptake of nutrients, especially phosphorus. Researchers at the Institute for Research in Ecology and Systematics have identified up to 53 different species of VAM fungi and have conducted extensive studies on their ecology, systematics, and cultivation (Herrera, interview). The Cuban government expects to produce 18 tons of VAM material for commercial use in 1994.

Other soil amendments and cultural practices have become widespread since the availability of inorganic fertilizers was reduced. These include green manure, crop rotations and intercropping (Gersper et al., 1993).

Minimum tillage. Cuba's minimum tillage activities started in 1968 as part of the program to prevent soil erosion. However, losing more than half its petroleum imports forced Cuba to accelerate research and implementation of minimum and no-till agriculture. The "multiarado" (multiplow) is a unique Cuban invention that emerged from the "Movimiento de Innovadores" (the Innovators' Movement) and Cuban mechanization research. This implement can be adapted to both tractor and oxen and is designed to save fuel and conserve soil (Lage, television interview).

Animal traction. In 1992, Cubans had less than half as much fuel for agricultural production as in 1990

(Lage, television interview). The fuel shortage in the countryside has been overcome by animal traction. After almost eliminating oxen from the countryside in the 1970s, Cuba now has trained 108,000 oxen and is training another 100,000. Oxen now are a common feature of the rural landscape. Since tractors have been replaced with oxen, farming implements are being redesigned to fit oxen and to conserve soil. Cuban agricultural engineers have already produced more than 70,000 new farming implements that fit oxen rather than tractors (Lage, television interview).

A fundamental change in strategy

These are just some examples of the appropriate technologies that now characterize Cuban agriculture. Some represent renewed implementation of old technologies; others are clever modifications of technologies developed somewhere else; still others are Cuban inventions. The last category includes what appear to be major scientific and technological breakthroughs, made possible by the Cuban Revolution's investment in science and education for the last 30 years. Cuba has only 2% of the Latin American population but 11% of its scientists (Rosset and Benjamin, 1993). This large number of scientists, along with a well-developed and centrally coordinated scientific infrastructure, allowed Cuba to generate new ecological technology at a rapid rate, while retraining conventional agricultural scientists in ecologically sound technology.

The accelerated implementation of new technology also has a negative side, however. Some Cuban researchers are concerned about the lack of appropriate testing before a technology is implemented, a consequence of the food crisis during the "Special Period." This is an interesting reversal of the common phenomenon of scientists becoming frustrated with bureaucratic impediments that delay the implementation of a new technology. In adapting and modifying old techniques (vermiculture, animal traction, biological control), Cubans have used a new discourse under which these technologies are not seen as "backward." Rather, they represent "cutting-edge appropriate technologies," or "thought-intensive technologies." This could indicate the long-term commitment of Cuban officials to low-input agriculture. These technologies not only may allow Cuba to survive under high uncertainties but also may release it from the economic dependence that characterizes most agricultural economies in Latin America.

Alternative Organization of Labor

An alternative organization of labor has become necessary in part because of the move toward appropriate technology. With the return of animal traction and low-input agriculture, more labor is needed in the countryside. Cuba has faced this challenge through various policy changes that give priority to agricultural labor, provide incentives to city workers for volunteer work in the countryside, and stimulate reestablishment of rural communities.

Volunteer workers

A volunteer program established to solve the immediate problem of supplying food to the cities is seen as a short-term solution (Deere, 1993). Since 1990, 350 agricultural labor camps have been constructed to accommodate the volunteers. Most of these term workers are people from the city who volunteer to work in agriculture for between two weeks and two years. One such labor camp is Las Marias, in Artemisa, Havana Province. This camp accommodates 320 workers, both males and females, in rooms with 5 to 6 people each. Like the others, this camp has all the necessities, including collective dining facilities, a doctor, and a nurse. The monthly salary for the volunteers is a minimum of $225 (Cuban pesos; 1 peso is equivalent to US$1 at the official exchange rate), which is comparable to that of a university professor ($250). However, a volunteer whose regular job pays a higher salary will continue to get that salary while in the labor camp. Besides a relatively high minimum wage, agricultural workers are offered a bonus based on productivity and the quality of their work. This additional salary often doubles the base salary (Martínez, interview).

Reestablishment of rural communities

Labor camps that rely on voluntary workers are seen as a temporary solution to the food crisis in Cuba during the "Special Period." On the other hand, according to Martínez (interview), Cubans see reestablishing rural communities as the long-term solution to the labor shortage in the countryside and to the more philosophical problem of the separation of people from nature. Under various rural development programs, the Cuban government is hoping to recreate the rural communities that were lost with the massive rural exodus caused by agricultural mechanization and the classical model of agricultural development.

These programs include electrification and the construction of housing, clinics, community centers, child care centers and roads. One of the most successful plans for rebuilding rural communities is the "Plan Turquino," which covers 19,594 km^2 of mostly mountainous land where coffee, cacao, pastures and other crops are grown. The government has constructed 142 camps to accommodate young men and women who exchange two years of agricultural labor for their two years of military service. It also offers low-cost housing to new couples that decide to stay in the region to start a family and work in agriculture. By 1992, 114,000 housing units with electricity had been constructed as part of the Turquino plan (Cuban Ministry of Agriculture, Appendix). This has repopulated the region and increased agricultural production.

Labor reorganization on state farms

Significant labor reorganization has also occurred within what used to be the large state farms, culminating with the cooperativization of the state sector. Except those that produce sugar cane and perhaps rice, each state farm is a mosaic of smaller production units, all managed by a central administration. Laborers used to be given specialized tasks and were assigned according to the demands of the farm as a whole. For example, a work crew might spend three days harvesting in one production unit and then be moved to another. Later, to stimulate a stronger link between

workers and the land, each work crew became associated with only one production unit, from planting to harvesting. According to Martínez, the head of the economics department of a state farm (interview), the hope was that they would make greater efforts to preserve the productivity of the land they worked. In addition, material incentives were offered to increase the production unit's productivity. Also, greater efforts were made to use local labor instead of migrants (Martínez, interview). By the end of 1993, this labor reorganization was taken a step further, when the government decided to turn the state farms over to farm workers' cooperatives. The effect that this unprecedented action will have on the further development of alternative agriculture is not yet known.

Farmer/scientist interactions

The more ecologically based the technology, the more site specific it must be. Consequently, Cuba has developed a system in which farmers and farm workers from the state and private sectors interact with off-farm scientists to determine the most efficient way to manage the production unit and to develop appropriate technologies for it. This helps those who have a detailed intimate local knowledge of their own circumstances to interact with those who can provide more general, theoretically based knowledge that requires them to keep at some distance from the particular site (Levins, 1990). Also, when the state farms were still in existence, some members of the technical staff, who formerly were based in the central administrative office of the farm and paid only occasional visits to the production units, were transferred to the units and became part of the units' regular staffs. This resulted in greater communication between the farm workers who did the field tasks and the technical staff who made recommendations on what should be done. That generated a continuous flow of knowledge from the farm workers and some independent farmers to the technical personnel, and visa versa. With the recent elimination of the state farms, it is not clear how technical assistance will be organized.

Alternative Planning

Increasing food production

Alternative planning reflects the urgency of the Cuban food situation. The sudden shift to a low-input agriculture and the elimination of agrichemicals inevitably have reduced yields (Deere, 1993). In combination with the loss of a large fraction of their imports, which included various items that had become part of Cubans' regular diet, these yield reductions have resulted in a food crisis. Food scarcity during the "Special Period" is evident all over Cuba, but it is mostly felt in Havana, which has 30% of the nation's population and has relied on other provinces for food (Benjamin et al., 1987; Deere, 1992). Since 1989, protein intake has fallen by 30% (Pérez Martin, interview). The economic blockade imposed by the U.S. has made a bad situation even worse, since instead of importing food from Miami (only 90 miles away), Cuba must import food from Europe, Asia or South America, which sometimes triples the cost of transportation (Lage, television interview).

By 1989, Cuba was already on its way to reducing food dependency as part of the "rectification process," a process of repoliticization generated by the growing disenchantment with the Soviet model of development, and by a renewed interest in the ideas of Ernesto Ché Guevara, who stressed that social and economic development were inseparable (Tablada, 1987; Levins, 1993). The National Food Program was approved in December 1990 by the National Assembly. However, it was developed under conditions different from those of the "Special Period," and therefore lacked the resources required to achieve its goals (Deere, 1993).

To address these problems, Cuba has developed various food programs, primarily in the cities, where the food crisis is most evident. Changes have been made in land use and agricultural planning to reflect the priority of food production during the "Special Period." Municipal and community gardens are being promoted in Havana and other urban centers. Each social center (including schools, hospitals, child care centers, factories, and state agencies) is encouraged to plant its own garden to supply vegetables, fruits and other foods to the people at the centers. Our delegation saw such gardens in almost every research center that we visited, but we could not verify whether other social centers have them. Changes in land use planning reflect the complex task of balancing food production priorities with the increasing need for foreign exchange when former agricultural inputs have been reduced by more than half. A recent evaluation of Cuba's food program under the "Special Period" showed mixed results, with important gains made in the production of vegetables and "viandas" (an assortment of root crops that are basic to the Cuban diet), but setbacks in the production of animal feed, grains, and legumes (Deere, 1993; Enríquez, 1994).

The sugar cane strategy

The problem of providing an adequate food supply leads to an important question related to sugar cane. This crop still occupies 60% of Cuba's nonpasture agricultural land. Sugar and its byproducts still account for 75% of Cuban exports (Pastor, 1992; Preeg, 1993), although production was down in 1992. (In a speech given in November 1992 [Appendix], Fidel Castro acknowledged that sugar cane production was unlikely to reach 7 million metric tons, and would be down more than 1 million metric tons from previous years.) According to Lage (television interview), Cuba is not going to abandon its sugar cane strategy. Even in the "Special Period," sugar cane is Cuba's most important economic resource. Despite low prices on the international market and lower productivity because of the lack of agrichemical inputs, especially fertilizers, sugar cane is still Cuba's main source of hard currency.

The reason is that "sugar cane is not just sugar. . . . The sugar industry includes important related industries based on sugar byproducts" (Lage, television interview). Today Cuba has a well-developed infrastructure for the processing of sugar and its byproducts. There are 60 factories that produce sugar byproducts such as alcohol and saccharine for animal nutrition. Also more than 200 factories produce animal feed using sugar as the main source of digestible energy. They also produce filter cakes, a processing byproduct that is used as fertilizer and as a raw material for pro

duction of earthworm compost. A new pharmaceutical product, PPG (policosanol), which has been described as "the most important pharmacological advance for the reduction of cholesterol to date" (a report from the University of Geneva, quoted by Carlos Lage during the television interview) uses a sugar cane byproduct as its main raw material, and is being produced industrially for consumption by tourists and for possible future export.

Organic intensification

The main strategy for agricultural diversification consists of increasing the production of food crops while maintaining current sugar cane production, rather than substituting food crops for sugar cane (Lage, television interview). This does not necessarily imply the cultivation of more land, since all arable land is already in agriculture. But it includes the organic intensification of some agricultural systems. For example, the area devoted to cattle pasture is scheduled to be reduced through Voison Rational Pasture Management. This is an intensive grazing system that uses electric fencing to confine cattle to smaller areas that are systematically rotated. Cattle urine and feces are used to fertilize the pastures, and the animals' diet is supplemented with protein from nitrogen fixing trees, such as *Leucaena* and *Glisina*.

Another initiative to increase food production without additional agricultural land is the construction of "organopónicos" in Ciudad de Avila for producing vegetables and "viandas." These consist of cement beds constructed within the city limits that are filled with a very fertile mix of soil and manure. Initial results have been encouraging. According to Peter Rosset, a member of our delegation who recently returned to Cuba in August 1993, the "organopónicos" in Ciudad de Avila have made up for the city's food deficit created by the "Special Period."

Besides these initiatives, it has become standard practice in Cuban agriculture to rotate and intercrop export crops with food crops and to grow each crop on the soils best suited to it. For example, intercropping sugar cane with soybean can guarantee a protein source for the population (either as vegetable protein or as feed for pigs, the main meat consumed in Cuba) while maintaining the production of the main export crop that generates the hard currency needed for fuel and other imports needed by the economy.

Environmental Preservation

Environmental preservation is at the center of the "Alternative Model." An indigenous ecology movement in Cuba has been growing since 1975, when the Commission for Environmental Protection was created. In 1981, Law #33 on Environmental Protection and Rational Use of Natural Resources was passed and the National System of Norms for the Protection of the Environment was instituted. This system involves the participation of various local grassroots organizations (Organos Locales de Poder Popular) in parallel with the central administration.

Cuba has four UNESCO Biosphere Reserves (ranging from 25,000 to 127,000 ha), and two national parks. Also, there are 58 protected areas and five Natural Monument Reserves for scientific use.

The political character of the Cuban environmental movement is very different from that of developed world. According to Levins (1990, p. 126), "Cuban ecology activists are political, committed revolutionaries who see their struggles for ecologically sound policies as part of the duties of communists in building a new society with its own relation to nature." These activists have been very influential in making the population more environmentally consciousness through mass organizations such as unions and the Women's Federation. The crisis generated by the events of 1989 helped legitimize ecologists in all facets of Cuban life, but was particularly important in legitimizing sustainable agriculture (Levins, 1990; 1993).

Conclusions: Lessons from the Development of Sustainable Agriculture in Cuba

The development of sustainable agriculture in Cuba was a result of external and internal pressures. On one hand, the sudden loss of almost all trade with the Soviet Union and Eastern Europe left Cuba with extreme shortages of fuel, pesticides and fertilizers. On the other hand, there was a growing realization that an agriculture that depended on costly inputs and environmentally unsound practices could not maintain the conditions of production for much longer; this realization led to increased investment in research and development of alternative practices. Together, these pressures resulted in perhaps the biggest recent experiment in the transformation of agriculture. Although the experiment has not been completed, some preliminary results seem promising.

The Cuban experiment offers a unique opportunity to examine not only the implementation of appropriate technology on a massive scale, but also the development of a sustainable agriculture within an ideology of racial, economic and social equity. Concerns for the well-being of the population have been molding the development of agriculture in Cuba since 1959. It was this concern that led to the banning of certain pesticides and the search for alternatives. However, the goal of providing an entire population with adequate nutrition under conditions of underdevelopment and inadequate technical knowledge made it urgent to find short-term solutions. That led to an emphasis on increasing production, with environmental and other long-term concerns relegated to secondary importance. In that sense, the events of 1989 were eye-opening for Cuban planners. Since then, food self-sufficiency has become their number one priority (as proclaimed, for example, in a speech by Fidel Castro in 1991 cited in the Appendix).

Agriculture in most developed countries, but in particular the United States, suffers from almost the opposite problem. The crisis of overproduction has resulted in depressed commodity prices, accumulation of enormous debt by farmers, and the resultant degradation of the rural sector. Poverty and ignorance are not the major forces hindering the development of sustainable agriculture in the U.S. Institutionalized greed makes profitability the only reason for inventing and promoting technologies (Levins, 1990). Cuba's lack of this barrier has helped the development and promotion of its alternative model.

Other aspects of the Cuban experience might provide insights for proponents of

alternative agriculture elsewhere. First, the reconstruction of integrated rural communities appears to be an essential component of Cuba's sustainable agriculture program. However, rather than isolated self-contained units, these communities are conceived as interdependent, forming part of an integrated rural society. Centralized/democratic planning is relied upon to prevent the anarchism and exclusionism that could spring from a purist and myopic bioregionalist approach. This centralized/democratic planning has allowed Cuba to move toward sustainable agriculture at a rapid pace.

Second, the Cuban experience also calls into question the small-is-better ideology of some sustainable agriculture movements, at least for a modern, complex society. Cuban planners distinguish between the unit of planning and the unit of production. To take advantage of economies of scale and to satisfy larger societal goals, the planning unit should be large. However, to maintain the ecological integrity of the region and to benefit from the intimate knowledge of local conditions, the production units should be much smaller, forming a mosaic of production systems (Levins, 1990).

Third, interactions of farmers and farm workers with researchers and other technical people is promoted as a continuous process, ideally taking place on terms of equality and mutual respect. Farmers and farm workers have intimate knowledge of their environment and are continually inventing and adapting technology. This knowledge should be valued and considered part of the scientific enterprise. Researchers and other technical people may lack the local and specific knowledge of farmers and farm workers, but have the training to put that particular knowledge in a broader context, so that it may be refined, generalized and made available to others.

Finally, this experiment in Cuba has led to the realization that there is no one pathway to development. The traditional developmentalist approach led Cuba to embark on the "Classical Model" of development for the first thirty years of the revolution. This was thought to be the only possible pathway. The Cuban initiatives on low-input sustainable agriculture challenge this developmentalist ideology and provide an alternative model.

The changes in Cuba's agriculture that we observed are consistent with the tenets of sustainable agriculture. However, because their origins are complex and involve enormous economic pressures, they might not represent a genuine change in philosophy. Rather, they simply could be a temporary response to the crisis.

On the other hand, Levins (1993), who has worked with Cuban scientists since the 1960s, argues that the roots of the changes that led to sustainable agriculture in Cuba go back further than the "Special Period":

> The socialist economic model starts with the premise that the use of nature must be the result of conscious choices rather than the outcome of individual profit-seeking behaviors. In the absence of private interests favoring the increased use of external inputs (fertilizers, pesticides) in agriculture, debates about the technological strategy are clashes of opinion, not interest. This makes it possible for the ecological option to win. (p. 59)

The distinction is important because if circumstances change sharply — for example, if the U.S. economic blockade is lifted, so that Cuba can obtain cheap agrichemicals and petroleum — only a true change in philosophy will insure that Cuba would not return to the less sustainable pathway.

It is too early to tell whether this experiment will take Cuba out of its current short-term crisis and its long-term dependence. Whatever the outcome, it is an experiment in low-input sustainable agriculture like none other in the world. Anyone concerned with the development of sustainable agriculture should pay close attention to this potentially transcendental event.

References

1. Añe, L. 1992. La biotecnología en la agricultural cubana: Análisis preliminar. Boletín de Información sobre la Economía Cubana 1:11-18.
2. Benjamin, M., J. Collins, and M. Scott. 1987. No free lunch: Food and revolution in Cuba today. Institute for Food and Development Policy, San Francisco, California.
3. Carroll, C.R., and S.J. Risch. 1990. An evaluation of ants as possible candidates for biological control in tropical annual agroecosystems. In S.R. Gliessman (ed). Agroecology. Springer Verlag, New York, N.Y. pp. 30-46.
4. Castiñeiras, A.S. Caballero, G. Rego, and M. González. 1982. Efectividad técnico-económica del empleo de la hormiga leona *Pheidole megacephala* en el control del tetuán del boniato *Cylas formicarius elegantulus*. (Technical and economic effectiveness of the use of the ant lion *Pheidole megacephala* to control the sweet potato borer *Cylas formicarius elegantulus*.) Ciencia, Tecnología y Agricultura (Cuba), Suplemento 1982:103-109.
5. Deere, C.D. 1992. Socialism on one island? Cuba's national food program and its prospects for food security. Working Paper Series No. 124. Institute of Social Studies, The Hague, Netherlands.
6. Deere, C.D. 1993. Cuba's national food program and its prospects for food security. Agriculture and Human Values 10:35-51.
7. Dlott, J., I. Perfecto, P. Rosset, L. Burkham, J. Monterrey, and J. Vandermeer. 1993. Management of insect pests and weeds. Agriculture and Human Values 10:9-15.
8. El-Gamal, M.S. 1992. Interactions between *Azotobacter* spp. and *Rhizobium sesbani* in the rhizosphere of *Sesbania sesban* (L.) Merrill plants and its efficiency on growth and symbiotic nitrogen fixation. Zentralblatt für Mikrobiologie 147:112-118.
9. Enríquez, L. 1994. The question of food security in Cuban socialism. Paper presented at the 18th International Congress of the Latin American Studies Association, Atlanta, Georgia, March 10-12.
10. Gersper, P., C. Rodriguez Barbosa, and L. Orlando. 1993. Soil conservation in Cuba: A key to the new model for agriculture. Agriculture and Human Values: 10:16-23.
11. Groff, G.W., and C.W. Howard. 1924. The cultured citrus ant of South China. Lingnan Agricultural Review 2:215-218.
12. Huang, H.T., and P. Yang. 1987. The ancient cultured citrus ant. BioScience 37: 665-671.

13. Levins, R. 1990. The struggle for ecological agriculture in Cuba. Capitalism, Nature, and Socialism 5:121-141.
14. Levins, R. 1993. The ecological transformation of Cuba. Agriculture and Human Values 10:52-60.
15. Pandey, A., and S.T. Shende. 1991. Effect of *Azotobacter chroococcum* inoculation on yield and post harvest seed quality of wheat (*Triticum aestivum*). Zentralblatt für Mikrobiologie 146:489-494.
16. Pastor, M. 1992. External shock and adjustment in contemporary Cuba. Working paper. The International and Public Affairs Center, Occidental College, Los Angeles, California.
17. Pérez Marín, E., and E. Muñoz Baños. 1991. Agricultura y alimentación en Cuba. Editorial de Ciencias Sociales, Havana.
18. Preeg, E. 1993. Cuba and the new Caribbean economic order. The Center for Strategic and International Studies. Vol. XV, No. 2, Washington, D.C.
19. Reddy, M.V., T.K.R. Reddy, and A.R. Alagawadi. 1991. The seed-born nature of *Azotobacter chroococcum* in sorghum (*Sorghum bicolor* [L.] Moench). Zentralblatt für Mikrobiologie 146:553-556.
20. Rosset, P.M., and M. Benjamin (eds). 1993. The Greening of Cuba's Agriculture. Ocean Press, Albourne, Australia.
21. Shishkoff, N. 1993. New approaches to plant pathology in Cuba. Agriculture and Human Values 10:24-30.
22. Tablada, C. 1987. El pensamiento económico de Ernesto Ché Guevara. Ediciónes Casa de las Americas, Havana, Cuba.
23. Thrupp, L.A., and T. Pérez 1989. Breaking chemical dependency in agriculture: The remarkable case of Cuba. Unpublished manuscript. Energy and Resource Group, Univ. of California, Berkeley.
24. Vandermeer, J.H., J. Carney, P. Gersper, I. Perfecto, and P. Rosset. 1993. Cuba and the dilemma of modern agriculture. Agriculture and Human Values 10:3-8.
25. World Health Organization. 1989. World Health Organization Yearbook, 1989. Geneva, Switzerland.

Appendix. Delegation members and information sources.

Some information presented in this article was obtained from direct interviews, television interviews, and speeches published by the Cuban press. Interviews were conducted by members of the International Scientific Delegation and Fact Finding Mission on Low Input Sustainable Agriculture in Cuba. The delegation traveled to Cuba from November 20 to 29, 1992.

Delegation Members

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Journalist
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Historian of Science
Evergreen State College

Carmen Rodríguez-Barbosa
Ecologist
Univ. of Michigan at Ann Arbor

Jeff Schatz
Environmentalist and businessman
Los Angeles, California

Nina Shishkoff
Plant pathologist
U.S. Dept. of Agriculture

John Vandermeer
Ecologist
Univ. of Michigan at Ann Arbor

Direct Interviews

1. Dr. Ricardo Delgado Diez, Director, Soil Institute; Bernardo J. Calero, Head, Microbiology Dept., Soil Institute; Raul Espinoza, Researcher, National Institute of Agricultural Sciences. (Interviewed by Paul Gersper and Carmen Rodríguez-Barbosa.)
2. Dr. Gerardo Herrera, Researcher, Center of Ecology and Systematics. (Interviewed by John Vandermeer.)
3. Pedro Pablo Martínez, Head, Economics Dept., *Empresas de Cultivos Varios*, a state farm in Artamisa, Havana Province. Interviewed by various members of the delegation during a visit to the farm. The delegation also interviewed many farm workers in the Las Marias Labor Camp, which belongs to the same state farm.
4. Dr. Marusia Nalimova, Plant Pathologist, Institute of Plant Health. (Interviewed by Nina Shishkoff.)
5. Jorge Ovies, Director, National Institute of Plant Protection Research, Ministry of Agriculture. (Interviewed by Ivette Perfecto.)
6. Dr. Enrique Pérez Marín, Chief, Agro-information Research, Ministry of Agriculture, and Economics Professor, University of Havana. (Interviewed by various members of the delegation.)

Television Interview

1. Carlos Lage, member of the Political Bureau and Secretary of the Executive Committee of the Council of Ministries; interviewed on the television program *Hoy Mismo*, November 6 and 11, 1992. The interview was reprinted in the newspaper *Granma*, November 10 and 14.

Speeches by Fidel Castro

1. Remarks to sugar cane cutters from the *1ro de Mayo* contingent, November 23, 1992. Published in the newspaper *Granma*, November 25.
2. Remarks to the 5th Congress of the National System of Agriculture and Forestry Technicians, 1991. An unpublished copy of the speech was obtained from the Cuban Ministry of Agriculture.

Information Bulletins and Unpublished Data

1. The National Institute of Plant Protection Research publishes a series of bulletins on new developments in plant protection, through the Center for Agricultural Information and Documentation, Ministry of Agriculture. The following were used in this article:
   - Applicación effectiva para el combate del picudo negro de plátano. 1990.
   - *Trichogramma* spp.: Control biológico de plagas in diferentes cultivos. 1990.
   - Los nemátodos parasíticos del tabaco y su control. 1990
   - Tu amiga la hormiga león. 1990.
   - El picudo negro del plátano. 1991.
   - La mosca blanca en el cultivo del tomate. 1991.
   - *Metarhizium anisopliae*: Bioinsecticida de gran espectro de acción. 1991.
   - *Verticillium lecanni*: Insecticida biológico para combatir homopteros y otras plagas. 1991.
   - La sigatoka amarilla en el cultivo del plátano. 1991.
2. Ministry of Agriculture: Unpublished statistics for 1991 and 1992.

Composting Act Picks Up Congressional Co-Sponsors

The Executive Composting Act, a bill (H.R. 2292) introduced last year in the House of Representatives which urges the President and the nation's governors to adopt backyard composting at their official residences, now has 72 co-sponsors. According to Rep. George Hochbrueckner (D-N.Y.), who introduced the bill, at least two governors now compost: Zell Miller of Georgia, and Jim Edgar of Illinois. Composting by the country's other governors and the President would set a positive example both to individuals and to federal and state government agencies, according to Rep. Hochbrueckner.

"Composting could be used to manage as much as 60 percent of municipal discards, significantly reducing the amount of solid waste sent to landfills," according to the bill, which is now awaiting committee action. "Finished compost provides a valuable soil amendment that can improve soil quality and stability, help prevent soil erosion, and reduce the demand for chemical fertilizers." For more information, contact Rep. Hoechbrueckner's Washington office at (202)225-3826.

Midwestern land-grant university scientists' definitions of sustainable agriculture: A delphi study

G. Walter and A. Reisner

Abstract. *What scientists include among the essential attributes of sustainable agricultural systems can influence the development of agricultural research agendas and how research is done. Current perspectives on sustainability place varying emphasis on environmental and agrarian values and propose different amounts and kinds of change in agricultural production, agricultural science, and rural social institutions. In a delphi study, agricultural scientists at North Central region land-grant universities considered environmental management and development of new farming technologies as essential to a definition of sustainable agriculture, but gave little importance to social or scientific restructuring. With some qualifications, we characterize their view of sustainability as a stewardship perspective that does not include social considerations and explicitly rejects radical social change.*

Key words: agricultural values, delphi method, science policy, sociology of science, land-grant universities

Introduction

People with different perspectives on agriculture's place in nature and society disagree on their definition of sustainable agriculture (Douglass, 1984; Jackson, 1984; Freudenberger, 1986; Allen and Sachs, 1991; Hamlin, 1991; Kloppenburg, 1991a,b; Levidow, 1991; Flora, 1992; Molnar et al., 1992). Most sustainable agriculture proponents advocate preserving and protecting natural environments. However, they differ dramatically in other goals for agriculture and in the changes they would require in agricultural production and the structure of rural and agricultural institutions (Douglass, 1984; MacRae et al., 1989). Some argue that sustainability means producing sufficient food, by whatever means necessary, to feed a growing world population. Others would only allow technologies that cause minimal disturbance to the physical environment off the farm. Still others would add the burden of enriching the social relationships and culture of rural communities (Berry, 1984; Douglass, 1984; Hamlin, 1991).

As the primary location of public agricultural research and technology development in the United States, land-grant universities (LGUs) are sources of both the problems and solutions of sustainable agriculture. They have earned considerable praise for their contribution to the productivity and efficiency of modern industrial agriculture (Evenson, 1979; Ruttan, 1982). Conversely, LGU research has been criticized for focusing too narrowly on production and efficiency goals and paying too little attention to the negative environmental and social consequences of that focus (Hightower, 1973; Berry, 1977; Jackson, 1987; National Research Council, 1989). Implicit in many of these criticisms is a belief that a reorientation of LGU research efforts would enable them to contribute more effectively to developing more sustainable agricultural systems.

Land-grant university scientists' own definitions of sustainable agriculture therefore play a critical role in charting the paths of research and technology development that emerge from individual research projects and from larger initiatives such as the Sustainable Agriculture Research and Education (SARE) program. The demands of their clientele, funding for specific research, and disciplinary interests often influence individual scientists' choice of research problems (Hadwiger, 1982; Busch and Lacy, 1983). However, the specific research topics and farming systems they choose to study are further determined by what they believe should be the goals of a sustainable system and the kinds of systems they believe will achieve them. Although we should not expect scientists' definitions of sustainable agriculture to be any more uniform than those of the critics of conventional research, research agendas are more likely to be built around the parts of their definitions where there is more agreement.

There is limited evidence that LGU scientists generally view sustainable agriculture more narrowly than many critics of conventional agricultural research and practice. A decade ago, Busch and Lacy (1983) found that LGU scientists were not very concerned about contemporary non-

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production issues other than the environment. Not long afterward, Ruttan (1987) noted that many in the land-grant system have slowly, and sometimes reluctantly, accorded the goals of environmental quality and social justice a comparable status with productivity. Recent work by Beus and Dunlap (1992, p. 376) suggests that the agricultural faculty at one LGU "are currently at considerable odds with much of the externalities/alternatives (ex/al) coalition . . . on virtually all elements of the alternative-conventional debate." However, the more recent emergence of programs such as SARE and the conservation provisions within the USDA National Research Initiative shows an effort to encourage scientists to study questions on the alternative agriculture agenda.

In this paper, we explore the attributes that a panel of midwestern LGU agricultural scientists use to define sustainable agriculture. We then analyze these attributes in terms of six dimensions introduced by Beus and Dunlap (1990) to distinguish conventional and alternative agricultural paradigms. This lets us explore points of potential agreement or conflict among the scientists and the various paths they envision to sustainability.

Methods

The study gathered information using an adaptation of the delphi technique, an iterative process of opinion gathering and feedback. Delphi is "a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone and Turoff, 1975). In a delphi exercise, informants who have specialized knowledge of, experience with or interest in a problem or its contextual domain separately propose answers to a question, then develop joint answers through successive refinements of their aggregated responses. Delphi allows them to define for themselves the topics or concepts relevant for consideration, rather than having them imposed by a survey, for example. It also lets them refine their definitions in light of those offered by others. By preserving participants' anonymity, it increases the chance that minority views will be introduced. It also allows people with diverse backgrounds or expertise and with no history of adequate communication to examine a complex problem (Linstone and Turoff, 1975).

We chose the delphi method, rather than more frequently used data collection methods, to reveal participants' varying perspectives on sustainability, highlight their points of agreement, and simulate how scientists in the same or different disciplines resolve value conflicts and contradictions. We structured our delphi process to do three things: allow participants more freedom to define the conceptual field of analysis than would be possible with a more structured survey questionnaire or face-to-face communication; offer participants an opportunity to consider the views of others with whom they might otherwise have little communication; and force a systematic narrowing and sharpening of views to highlight the fundamental bases of participants' "core definitions" of sustainable agriculture. The first and third of these objectives are partly contradictory; although the first step in the delphi process encourages expression of a wide range of viewpoints, the succeeding rounds' search for consensus can eliminate minority views from consideration. This contradiction is not entirely undesirable because it parallels how research agendas emerge when individuals' conceptualizations interact with peer groups' responses during project funding and review. Consequently, we report how the panel's definition of sustainable agriculture developed through all steps in the process.

Delphi panel selection and process

We identified 414 prospective delphi panelists using current mailing lists and directories for land-grant agricultural colleges, state agricultural and natural resource agencies, farmer and agribusiness organizations, and farm magazines and newspapers in the 12 North Central states. The three groups of non-scientist participants were included in the initial panel to enable their potentially different views on sustainability to be included. Prospective agricultural scientist panelists were selected using a stratified random sampling procedure that selected 8% of the pooled names of agriculture faculty members in six categories: animal sciences, crop production, social science, engineering, food and nutrition sciences, and forestry and natural resources. This yielded 241 initial agricultural scientist contacts.

Initial contacts in state agencies included state secretaries or directors of agriculture, natural resources, and environmental protection; public affairs directors for those agencies; and directors of other agency subdivisions with potential interest in sustainable agriculture. Prospective farmer and agribusiness organization participants included presidents or other top executives of organizations listed by the agricultural communications units of North Central land-grant universities. If the officials' names were unavailable, we sent the invitation to participate to the organization's mailing address. Prospective farm press participants were members of the National Association of Agricultural Journalists and the American Agricultural Editors Association whose publications are produced or widely circulated in the North Central region. (These are the primary professional associations for agricultural news writers and farm magazine writers and editors.)

All prospective participants received an introductory letter soliciting their participation; we encouraged the non-scientists who could not participate to appoint an alternate. Forty-nine percent of the scientists and 57% (234 members) of the entire group agreed to participate (Table 1).

All panelists received a first-round questionnaire asking them to name what they consider attributes of sustainable agriculture; they were encouraged to name as many as they wished. The 185 questionnaires returned, including 109 from agricultural scientists, yielded 556 statements of sustainable agriculture attributes. We removed duplications and rephrased similar statements to produce a list of 80 items encompassing the full range of attributes submitted. Of these items, 77 reflect attributes proposed by both scientist and non-scientist panelists, and three reflect attributes proposed only by scientist panelists. The non-scientist panel did not propose any attributes that were not also proposed by the scientists.

In the second round, the LGU scientists who responded in the first round selected up to 20 items from this list that they considered essential to sustainable agriculture,

Table 1. Delphi panel selection and membership.

Delphi step	Anim. Sci.	Crop Sci.	Soc. Sci.	Other[1]	Total LGU	Non-LGU[2]	Total Panel
Sample	52	92	45	52	241	173	414
Agreed to participate	32	55	15	18	120	114	234
First round[3]	26	51	14	18	109	76	185
Second round	25	50	13	16	104		
Third round	25	44	12	13	94		
Fourth round	16	36	9	12	73		

[1] Includes agricultural engineering, nutrition and food science, and forestry and natural resources.
[2] Includes state agricultural officials, farm organization officers and farm press.
[3] Comparison of distribution of participants and nonparticipants across disciplines in each round: first round, χ^2=10.4, d.f.=4, p<.05; second round, χ^2=12.2, d.f.=3, p<.01; third round, χ^2=12.0, d.f.=3, p<.01; fourth round, χ^2=6.9, d.f.=3, p<.10.

and indicated any items they considered not essential to sustainable agriculture. From the 104 responses, we prepared a second list of 26 items called essential by at least 25% of the panel. We mailed this to the 104 scientists who had responded to the second mailing and nine others whose first-round responses arrived too late to be incorporated into the 80-item list. We instructed participants to rank the 10 statements most strongly considered essential to sustainable agriculture; 94 returned ranked lists.

A final mailing arrayed the 26 items according to their average ranks; it also included a series of 5-point response items asking participants whether they would accept items identified by the group as inappropriate for defining sustainable agriculture. These questionnaires were returned by 73 panelists.

The number of LGU scientists participating in the delphi process declined gradually through the first three rounds, then dropped to about two-thirds of the 109 first-round respondents in the fourth (evaluation) round. Attrition thus limits interpretation of the final-round responses. In the first three rounds, the distribution across disciplines differed significantly (p<.05, χ^2 test) between participants and nonparticipants, with attrition lower among crop production scientists and higher among social scientists than for the sample as a whole.

Delphi Results

The initial list of sustainable agriculture attributes submitted by the delphi panelists (Table 2) included a broad range of issues, including environmental quality, technology choice, resource conservation, the temporal dimension of sustainability, and ethical concerns. The scientists (and the other first-round panelists) also submitted statements touching on rural community health, relationships between agriculture and the non-agricultural public, and issues of food safety, farm and farm sector economics, and the structure of agriculture.

Asked to select up to 20 of these attributes that they consider essential aspects of sustainable agriculture, more than half included the statement "minimal environmental degradation." Sizable proportions of the LGU scientists also chose other statements characterizing sustainable agriculture as environmentally benign, profitable, more diverse than the current production system (both on individual farms and across the farming sector), and stable over the long run. Less prominent in the scientists' narrowed definitions were productivity, safety and quality of the food supply, government agricultural programs, energy use, and the number and size of farms. In contrast to how some alternative agriculture advocates describe sustainable agriculture, more than one-third of the scientists marked "increases the number of farmers" as *inappropriate* in the definition of sustainable agriculture.

The list of attributes created and refined by the agricultural scientists suggests that the scientists agree on some aspects of what sustainable agriculture should be. However, some attribute statements in this collective "definition" appear to reflect opposite sides of the sustainable agriculture debate. Simply listing the attributes retained at the different stages of the delphi process is not sufficient to understand these inconsistencies and contradictions. Clarifying in more general terms the kind of sustainable agriculture the scientists envision will identify better where the panel's vision of sustainable agriculture is situated in the current debate, and the role that LGU agricultural scientists might play as the debate continues.

The remainder of our analysis attempts to interpret the delphi results according to a typology advanced by Beus and Dunlap (1990, 1991, 1992) that highlights key differences between conventional and alternative agriculture. Although the sustainable agriculture attributes on the panel's list have an underlying conceptual structure, with attribute statements clustering according to their environmental, technological, economic and other orientations, we will refrain from adding yet another "definition" of sustainable agriculture to an already crowded field. We chose the Beus and Dunlap typology for our analysis because it has been useful in distinguishing positions aligned with conventional and alternative agricultural paradigms (Beus and Dunlap, 1991, 1992). However, except for a study of the orientations of agricultural scientists at one land-grant university (Beus and Dunlap, 1992), the typology has not been used to characterize how LGU scientists look at sustainability.

Paradigmatic Dimensions of Conventional and Alternative Agriculture

Reviewing public statements of 12 prominent conventional and alternative agriculture proponents, Beus and Dunlap (1990, p. 609) concluded that the debate is between "fundamentally divergent paradigms" whose prescriptions for agricul-

Table 2. Identification and ranking of sustainable agriculture attributes and non-attributes.

	Round 2 (n=109)		Round 3 (n=93)
	% calling item essential	% calling item non-essential	Ave. rank
Retained on reduced (26-item) list			
Minimal environmental degradation	57	1	6.4
Maintains air and water quality	43	0	4.5
Considers regional/local differences	43	1	1.4
Makes fullest possible use of natural systems and on-farm resources	42	1	4.6
Preserves soil as medium for plant growth	42	2	3.6
Does not exceed land's long-term carrying capacity	41	0	3.2
Can be done over the long run	40	2	3.1
Takes advantage of all available technologies	39	7	2.7
Safe and economical weed/pest control	38	1	1.4
Includes flexible cropping systems	38	2	1.3
Is profitable for farmers	37	4	3.0
Supports basic and applied agricultural research	37	8	2.4
Uses holistic or systems approach to pest control	37	6	1.3
Balances farmers' profits with social concerns for water quality and food safety	36	6	4.4
Competitive in world economy	36	8	1.7
Substitutes management and information for purchased inputs	35	6	2.3
Integrates crop and livestock operations	32	6	1.4
Fair economic returns to land, labor, and capital	29	5	1.3
Reduces health risks for farmers and farm families	29	7	1.2
Minimal use of artificial pesticides and fertilizers	28	14	1.0
Reduces farm dependence on purchased inputs	27	7	0.5
Uses least-cost, safe technology	27	5	0.3
Increases diversity among farming operations	26	5	0.8
Increases diversity within farming operations	26	4	0.6
Improves soil	26	6	0.5
Provides good living as well as a way of life	25	6	0.6
Not retained on reduced list			
Reduces off-farm effects of agricultural production	22	5	
Can be done on a small scale (e.g., <1000 acres)	22	7	
All sectors of farm/food system resilient enough to prevent collapse due to sudden change	21	5	
Protects wildlife habitat	21	2	
Can be done on a large scale (eg., >1000 acres)	21	12	
Reduces input costs	20	5	
Creates/maintains stable rural communities	20	7	
Maintains high productivity	20	6	
Increases individual farm self-sufficiency	20	10	
Quality of product equals that from current methods	18	2	
Turns first to biological management tools	18	8	
Promotes genetic diversity	18	7	
Has realistically defined objectives	15	6	
Market-oriented	15	8	
Does not appreciably increase input costs	15	4	
Maximizes decision-making autonomy of individual producers	15	6	
Produces safer food	14	12	
Satisfies ethical or moral needs	14	15	

(continued)

Table 2. Identification and ranking of sustainable agriculture attributes and non-attributes (cont'd).

	Round 2 (n=109)		Round 3 (n=93)
	% calling item essential	% calling item non-essential	Ave. rank
Not retained on reduced list (cont'd)			
Applicable to at least 25% of cropland	14	17	
Adheres to Leopold's land ethic	13	17	
Consistent with farm operators' motives and goals	13	1	
Reduces tillage	13	3	
Relies on results of replicated trials	13	8	
Uses less energy	13	6	
Uses transgenic or otherwise modified plant/pest control	12	13	
Has a rational method for allocating resources among different social goals	12	17	
Matches labor availability	12	7	
Does not appreciably reduce yields	12	6	
Minimizes government regulation of agriculture	11	28	
Produces more energy than it consumes	10	12	
Respects property rights of farmers and others	10	4	
Reduces dependence on foreign oil	10	8	
Purchased inputs available at reasonable cost and when needed	9	6	
Does not add to national debt	9	21	
Removes barriers to entering farming	9	15	
Broadly accepted by public	8	7	
Produces higher quality food	8	15	
Increases rural employment	8	17	
Does not depend on expensive machinery	8	17	
Stabilizes rural population	8	13	
Broadly understood by the public	7	20	
Available to everyone	7	17	
Increases number of farmers	7	34	
Maintains high production	7	13	
Reduces uncertainty	7	19	
Easily implemented	6	28	
Maintains farmer numbers	6	22	
Credit is readily available to meet capital needs	6	13	
Reduces average size of farms	5	28	
Offers higher return on farmer's investment than current methods	5	20	
Provides subsidies where needed to maintain farm income and other objectives	5	30	
Easily managed	4	26	
Easily learned	3	26	
Reduces subsidies to producers and others	3	15	

tural practice and structure cleave along six primary dimensions. Three of these dimensions, whose poles respectively are centralization/decentralization, dependence/independence, and competition/community, reflect the recurring debate over agrarian vs. industrial values and institutions in modern agriculture. The other three, labeled domination of nature/harmony with nature, specialization/diversity, and exploitation/restraint, concern agriculture's place in the natural environment. According to Beus and Dunlap, these mark the difference between today's alternative agriculture movement and agrarian movements of the past.

Agrarian and structural dimensions

Centralization/decentralization. According to Beus and Dunlap, the conventional and alternative agricultural paradigms differ fundamentally regarding the most sustainable agricultural structure.

Whereas conventional agriculture proponents consider the decreasing numbers of farms as a sign of greater efficiency and progress, those with alternative views argue that the continuing concentration has made the agricultural system less able to respond to economic, political, and ecological change. The alternative paradigm argues for more farmers and decentralized processing and marketing systems; the conventional favors vertically integrated production units that in turn are fully integrated into national and international distribution channels.

Dependence/independence. Accompanying the conventional paradigm's preference for highly integrated production systems, according to Beus and Dunlap, is a belief that productivity and sustainability can best be achieved by large, capital-intensive farms relying on external sources of energy, credit, information, and other inputs. In marked contrast, the alternative paradigm calls for smaller farms and less dependence on distant sources of capital, technology, and other resources. Some people who support the alternative view also argue that information to create a sustainable production system must come from farmers' personal knowledge and experience as much as from the science-based recommendations of experts and specialists.

Competition/community. Beus and Dunlap also note how the two paradigms differ on the noneconomic aspects of farm and rural life. Conventional agriculture proponents attach the highest value to profits and markets and consider that the decline of rural communities, although unfortunate, was a necessary and worthwhile sacrifice for modern agriculture's greater productivity and efficiency. Arguments in favor of community, on the other hand, ascribe greater value to such noneconomic concerns as farm family health and well-being, the quality of local institutions and social relationships, and the esthetic quality of both the natural and the built environment.

Ecological and environmental dimensions

Domination of nature/harmony with nature. According to Beus and Dunlap (1990), beliefs about the relationships between humans and nature required in modern agriculture represent perhaps the most fundamental difference between conventional and alternative agricultural paradigms. Extreme versions of the conventional paradigm regard nature as consisting of resources to be controlled and used by the industrial forces of agricultural production. In contrast, alternative perspectives favor more harmonious integration of agriculture and the natural environment, in which agricultural practices imitate natural ecosystems and are subject to nature's constraints.

Exploitation/restraint. A second ecological or environmental dimension in Beus and Dunlap's typology highlights differences over the moral component of agriculture's relationships with both nature and society. On this dimension, the alternative view is that preservation of resources for future generations demands moderate consumption and resource-conserving technologies. Alternative agriculture adherents would internalize agriculture's social and environmental costs, with the extreme view calling for simpler, less materialistic lifestyles. On the other hand, the conventional paradigm claims that society has a moral responsibility to meet human needs using whatever agricultural methods are needed to maximize food and fiber production. Conventional agriculture proponents also place greater confidence in the ability of science and technology to increase agricultural productivity to meet future food and fiber needs.

Specialization/diversity. Beus and Dunlap argue that the two competing paradigms also differ in the degree of specialization required for a sustainable farm and food system. In the conventional paradigm, specialization and standardization are the source of the economic efficiency that modern farms must have to be productive and competitive. Efficiency requires specialization at the farm level and uniformity in production systems, including genetic uniformity in crops and livestock. Critics of this industrial model, on the other hand, call for greater genetic diversity, mixed crop and livestock production on individual farms, and variation among farms' production and distribution systems to suit local conditions.

Assigning statements to dimensions

We asked a judging panel of seven agricultural scientists, two farmers, and a farm organization official to assign each statement on the 80-item open-ended list of sustainable attributes to a pole of each of these six dimensions using Beus and Dunlap's (1990) inventory of the key elements of each dimension. Beus and Dunlap (1991) note that the paradigms and their associated dimensional poles are ideal types meant to help clarify the philosophical or ideological bases of statements about sustainability. However, when statements were being assigned to dimensional poles, the dimensions often appeared to overlap. That is, different judges, or even an individual judge, sometimes considered the same statement as representing different dimensions. The 10 judges classified just 44 of the statements identically, which suggests that the full dimensional typology may not be reliable for describing the delphi panel's collective definition of sustainable agriculture. On the other hand, the judges classified 77 of the 80 statements identically between conventional vs. alternative (without respect to specific dimensions), and assigned 72 of the statements to the same larger dimensional grouping (agrarian/structural vs. environmental/ecological). This suggests that the larger dimensional classifications can be useful in describing the findings.

Table 3 shows the final classification of attribute statements to dimensions used in the following analysis, using the judging panel's assignments. Where those yielded no clear classification, we interpreted them ourselves, using Beus and Dunlap's (1990) inventory of key elements.

Findings

First-round: Open-ended listing of attributes

A large majority (57 of 80) of the attribute statements initially submitted by LGU scientists on the delphi panel reflect positions consistent with the alternative agricultural paradigm. A smaller majority (45 of 80) are aligned with the agrarian/structural dimensions. Among the latter group, the largest number reflect a belief that sus-

Table 3. Sustainable agriculture attribute statements, by dimension.

Agrarian/Structural

Centralization
- Has a rational method for allocating resources among different social goals
- Has realistically defined objectives
- Competitive in world economy

Decentralization
- Considers regional/local differences
- All sectors of farm/food system resilient enough to prevent collapse due to sudden change
- Available to everyone
- Stabilizes rural population
- Increases number of farmers
- Maintains farmer numbers
- Removes barriers to entering farming
- Minimizes government regulation of agriculture

Dependence
- Can be done on a large scale (e.g., >1000 acres)
- Provides subsidies where needed to maintain farm income and other objectives
- Credit is readily available to meet capital needs
- Purchased inputs available at reasonable cost and when needed

Independence
- Can be done on a small scale (e.g., <1000 acres)
- Reduces input costs
- Does not appreciably increase input costs
- Matches labor availability
- Does not depend on expensive machinery
- Reduces farm dependency on purchased inputs
- Maximizes decision-making autonomy of individual producers
- Substitutes management and information for purchased inputs
- Easily learned
- Easily implemented
- Easily managed
- Reduces average size of farms
- Reduces subsidies to producers and others
- Reduces dependence on foreign oil

Competition
- Quality of product equals that from current method
- Fair economic returns to land, labor, and capital
- Is profitable for farmers
- Does not appreciably reduce yields
- Maintains high productivity
- Market-oriented
- Respects property rights of farmers and others
- Offers higher return on farmer's investment than current methods

Community
- Produces higher quality food
- Consistent with farm operators' motives and goals
- Creates/maintains stable rural communities
- Satisfies ethical or moral needs
- Increases rural employment
- Provides good living as well as a way of life
- Broadly accepted by public
- Broadly understood by the public

Environmental/Ecological

Domination of nature
- Maintains high production
- Reduces uncertainty
- Safe and economical weed/pest control
- Uses transgenic or otherwise modified plant/pest control

Harmony with nature
- Produces safer food
- Adheres to Leopold's land ethic
- Reduces health risks for farmers and farm families
- Uses least-cost, safe technology
- Turns first to biological management tools
- Makes fullest possible use of natural systems and on-farm resources
- Reduces tillage
- Improves soil
- Uses holistic or systems approach to pest control

Specialization
- Applicable to at least 25% of cropland

Diversity
- Includes flexible cropping systems
- Increases diversity among farming operations
- Increases diversity within farming operations
- Integrates crop and livestock operations
- Increases individual farm self-sufficiency
- Promotes genetic diversity

Exploitation
- Supports basic and applied agricultural research
- Takes advantage of all available technologies
- Relies on results of replicated trials

Restraint
- Can be done over the long run
- Preserves soil as medium for plant growth
- Does not exceed land's long-term capacity
- Reduces off-farm effects of agricultural production
- Protects wildlife habitat
- Minimal use of artificial pesticides and fertilizers
- Minimal environmental degradation
- Maintains air and water quality
- Balances farmers' profits with social concerns for water quality and food safety
- Uses less energy
- Does not add to national debt
- Produces more energy than it consumes

tainable agriculture should make farmers more independent of outside sources of credit and other inputs, and give them more autonomy in making decisions. Nearly as many statements deal with issues along the competition/community dimension, though these are more equally divided between conventional and alternative views. Statements identified with the environmental/ecological dimensions more clearly express alternative than conventional perspectives. The largest number of these statements deal with restraints on resource use and on enhancing agriculture's harmony with nature.

The collective definition of sustainable agriculture yielded by these lists includes both environmental and agrarian components, stressing harmony with nature, restraints on technology, producer independence (and profitability) and a more diverse producer sector. However, the number of attribute statements mentioning farming practices and inputs also suggests that many panelists see sustainability's primary goal to be avoiding environmental degradation through new or improved production technologies — a "green" variation of what Douglass (1984) has labeled the "food sufficiency" perspective. On the other hand, some panelists included attributes tapping a wider range of concerns than merely avoiding environmental degradation. Some said that sustainable technologies must integrate crop and livestock enterprises, a point related to increasing farm diversity. Others suggested attributes related to increased farm control/self-sufficiency, such as that sustainable farms should be easy to manage.

Second round: Selecting "essential" attributes

Asked next to identify up to 20 attributes they consider essential in their own definitions of sustainable agriculture, most panel members favored statements consistent with alternative positions on the six paradigmatic dimensions (Table 4). Large proportions of the 20-item lists included statements associated with environmental arguments (harmony, diversity, and restraint), and smaller majorities also included state-

Table 4. LGU scientists' choice of 20 essential attribute statements from open-ended list, by dimension and academic field.

Dimension	Number of statements in dimension	Percent selecting at least one statement in dimension					Average number of statements selected as percentage of statements in dimension				
		Animal Science (26)	Crop Science (51)	Social Science (14)	Other[1] (18)	All LGU Scientists (109)	Animal Science	Crop Science	Social Science	Other[1]	All LGU Scientist
Agrarian/Structural											
Centralization	3	50	53	50	50	51	18	22	19	24	21
Decentralization	8	58	75	79	61	69	13	15	15	14	15
Dependence	4	27	41	14	44	35	8	12	5	13	10
Independence	14	85	80	57	83	79	13	13	9	15	13
Competition	8	69	73	79	67	72	20	18	18	17	18
Community	8	58	57	64	56	58	11	13	14	13	12
Environmental/Ecological											
Domination of nature	4	50	51	36	56	50	14	17	9	16	16
Harmony with nature	9	81	78	79	89	81	27	22	18	26	23
Specialization	1	15	13	0	22	14	15	14	0	22	14
Diversity	6	69	73	57	67	69	22	30	25	19	26
Exploitation	3	58	65	36	44	56	36	34	12	22	30
Restraint	12	88	90	86	89	89	34	29	30	29	30
Total Agrarian/Structural	45	92	94	93	89	93	14	15	13	15	14
Total Environmental/ Ecological	35	96	96	93	89	95	27	26	21	25	26
Total Conventional	23	96	98	86	89	95	18	19	13	19	18
Total Alternative	57	96	96	93	89	95	20	20	18	20	20

[1] Includes agricultural engineering, nutrition and food science, and forestry and natural resources.

ments characteristic of alternative agrarian arguments for independence, decentralization, and community. However, 72% of the respondents selected statements consistent with conventional agrarian arguments for competition, and half or more identified statements favoring exploitation, centralization, and domination.

Nearly all the scientists included statements on their 20-item lists that were characteristic of both the conventional and alternative paradigms and of both the agrarian and environmental aspects of sustainability. Nearly one-quarter included only statements associated with the alternative paradigm, while another 14% listed only conventional attributes. This shows that the panel includes polar core groups of alternative and conventional agriculture proponents. There were few large differences among academic fields.

To remove the confounding effect of the differing number of statements that a scientist could select for each dimensional pole, we also computed the relative proportion of statements selected from those identified with each dimensional pole (Table 4). These show that although the open-ended list included more attributes identified with agrarian/structural concerns, the scientists included larger proportions of the environmental/ecological statements on their lists of essential attributes.

Compared with the 80-item list of attributes compiled from the panelists' open-ended submissions, the 26-item reduced list produced from the second round retained a considerably smaller proportion of attributes reflecting the agrarian aspects of sustainability (7 of 45) compared with environmentally oriented attributes (19 of 35).

Third round: Ranking essential attributes

In ranking the statements on the 26-item reduced list, large majorities of the scientists continued to regard both alternative and conventional and both agrarian and environmental statements as important (Table 5). However, they ranked environmental attributes, particularly those aligned with the exploitation/restraint di-

Table 5. LGU scientists' choice of 10 attribute statements for ranking from 26-item reduced list, by dimension and academic field.

Dimension	Number of statements in dimension	Percent selecting at least one statement in dimension					Average number of statements selected as percentage of statements in dimension				
		Animal Science (25)	Crop Science (43)	Social Science (12)	Other[1] (13)	All LGU Scientists (93)	Animal Science	Crop Science	Social Science	Other[1]	All LGU Scientists
Agrarian/Structural											
Centralization	1	44	26	50	54	38	44	26	50	54	38
Decentralization	1	36	21	42	38	30	36	21	42	39	30
Dependence	0										
Independence	2	52	49	67	46	52	26	27	42	31	29
Competition	2	60	65	42	62	60	34	41	29	35	37
Community	1	20	12	8	23	15	20	12	8	23	15
Environmental/Ecological											
Domination of nature	1	20	35	25	31	29	20	35	25	31	29
Harmony with nature	5	92	88	83	92	89	27	29	30	34	30
Specialization	0										
Diversity	4	64	74	67	38	66	24	32	27	15	27
Exploitation	2	84	77	33	77	73	62	51	17	50	50
Restraint	7	57	54	57	56	56					
Total Agrarian/Structural	7	92	86	83	100	89	31	28	35	35	30
Total Environmental/ Ecological	19	100	100	100	100	100	41	42	38	40	41
Total Conventional	6	92	95	58	92	89	43	41	28	42	40
Total Alternative	20	100	100	100	100	100	37	37	40	37	37

[1] Includes agricultural engineering, nutrition and food science, and forestry and natural resources.

mension, higher than those identified as agrarian (Table 6). Of the ten attributes with the highest average ranks, seven derive from alternative agriculture arguments and eight involve environmental concerns, including air and water quality and soil conservation.

All scientists included at least one statement aligned with the alternative, environmentally oriented position advocating restraint in the use of resources (Table 5). Large proportions also gave high rankings to items identified with the alternative poles of the other environmental/ecological dimensions. Although 89% of the scientists included at least one agrarian/structural statement among the ten items they ranked highest, the proportions choosing an item from any single pole of those dimensions were much smaller. The largest numbers ranked statements supporting competition (a conventional paradigm pole) and farmer independence (an alternative pole).

The scientists included a slightly higher proportion of environmental attributes among the ten highest from the 26-item list (41% vs. 30%). On the other hand, they selected nearly equal proportions of conventional and alternative paradigm statements (40% and 37%, respectively). As in the second round, statements identified with the two poles of the exploitation/restraint dimension were ranked highest when the number of statements selected is expressed as a fraction of the number identified with that dimension.

Thus, the scientists' collective definition of sustainable agriculture, when narrowed to its essential elements, is considerably more environmentally oriented than their open-ended lists. The agrarian aspects of sustainability — the number and size of farms, farmer dependence on inputs and input suppliers, and farmer participation in producing knowledge and developing technology — are decidedly secondary to environmental and scientific concerns. Though all the scientists included at least one agrarian statement in their final rankings, as a group they view sustainable agriculture more in stewardship than community-sustainability terms (Douglass, 1984).

Table 6. Average rank given statements on 26-item reduced list of essential attributes, by dimension and academic field.

Dimension	Number of statements in dimension	Animal Science (25)	Crop Science (43)	Social Science (12)	Other[1] (13)	All LGU Scientists (93)
Agrarian/Structural						
Centralization	1	1.0	1.1	3.4	3.2	1.7
Decentralization	1	1.8	1.2	1.7	1.3	1.4
Dependence	0					
Independence	2	1.2	1.1	2.1	1.7	1.3
Competition	2	1.7	2.5	1.9	1.8	2.1
Community	1	0.5	0.5	0.7	1.1	0.6
Environmental/Ecological						
Domination of nature	1	0.9	1.7	1.1	1.4	1.4
Harmony with nature	5	1.5	1.6	1.4	1.4	1.4
Specialization	0					
Diversity	4	0.9	1.1	1.0	0.7	1.0
Exploitation	2	3.1	2.6	1.2	2.3	2.5
Restraint	7	3.9	3.5	3.8	3.8	3.7
Total Agrarian/Structural	7	1.3	1.4	2.0	1.8	1.5
Total Environmental/ Ecological	19	2.4	2.3	2.2	2.2	2.3
Total Conventional	6	1.9	2.2	1.8	2.1	2.0
Total Alternative	20	2.2	2.1	2.2	2.1	2.1

[1] Includes agricultural engineering, nutrition and food science, and forestry and natural resources.

"Non-attributes" of sustainable agriculture

The statements the scientists considered inappropriate for defining sustainable agriculture also show that they subordinate or exclude sustainability's structural dimensions. Of the 80 items on the original list (Table 2), 23 were identified by at least 15% of the scientists as attributes that should not be used to define sustainability. Eighteen of these "non-attributes" are identified with agrarian/structural dimensions, and the largest portion of these are consistent with the alternative agriculture paradigm.

Furthermore, most scientists in the fourth round said that reversing the trend toward fewer and larger farms, improving rural social structure, making farming accessible to persons with all levels of management skills, and addressing goals that are not specifically agricultural should not be a part of a definition of sustainable agriculture (Table 7). However, most also

Table 7. LGU scientists' willingness to accept categories of items identified as inappropriate attributes of sustainable agriculture, mean score[1] by academic field.

	Animal Science (14)	Crop Science (35)	Social Science (8)	Other[2] (12)	Total (69)
Slows or reverses the trend toward fewer and larger farms	1.8	2.5	1.4	2.5	2.2
Is consistent with current measures of agricultural success	2.6	2.4	2.1	2.3	2.4
Improves rural social structure	2.2	2.7	1.9	2.9	2.6
Is accessible to persons with all levels of management skills	1.5	2.1	2.1	2.8	2.1
Addresses specific "non-agricultural" goals (e.g., reduced energy use, minimum income, etc.)	2.1	2.6	2.3	2.6	2.5

[1] Scoring: 1=cannot accept definition that includes this; 2=does not belong in definition, but would accept one that includes it; 3=inclusion makes no difference in acceptability of definition; 4=belongs in definition, but would accept definition that does not include it; 5=cannot accept a definition that does not include this.

[2] Includes agricultural engineering, food and nutrition sciences, forestry and natural resources.

said that a definition that judges agricultural success strictly according to productivity measures also might be unacceptable, a finding consistent with their including environmental nondegradation as essential for sustainability. As with the results already reported, there were few differences among academic fields.

Summary Observations

Because the delphi method is iterative and interactive, rather than based on the independent responses of each participant in the sample, it does not lend itself to the standard statistical tests of whether the results can be generalized to a larger population. Furthermore, the collective, aggregated list of attributes masks some variation among the lists submitted by individual panelists. Yet some aspects of the delphi results are clear enough to permit us to characterize the way LGU scientists in the North Central Region define sustainable agriculture and the path to achieve it.

For example, most LGU scientists participating in the delphi exercise favor a definition of sustainable agriculture that adds environmental concerns to otherwise conventional views of agriculture's goals and place in society. Throughout the exercise, they consistently gave most of their attention to environmental attributes. Conversely, many said that slowing the trend toward fewer and larger farms, improving rural social structure and simplifying management skills should not be defining features of sustainable agriculture. Although they incorporate alternative perspectives into their view of the environmental requirements of sustainability, their view of its social aspects gives priority to conventional values of production and efficiency.

The tendency to exclude social structure and noneconomic values from the collective definition suggests that LGU scientists generally see sustainable agriculture largely in terms of stewardship, that is, producing food and fiber in ways that minimize environmental degradation but that do not impair farm profits. Many support making the fullest possible use of natural systems and on-farm resources, which echoes the stewardship perspective's emphasis on locally adapted production and reduced reliance on purchased inputs. On the other hand, few envision an agricultural system that includes more diversified farms, and most rejected statements that sustainability should emphasize farmer and community independence, interaction or power.

The responses suggest satisfaction with any farming system that maintains or increases current production levels without significantly harming the environment. Although the scientists clearly favor more ecologically harmonious agricultural production, most consider that the analysis should end with the farm and the natural systems it touches; community and regional social institutions are secondary at best. Few scientists seem willing to breach the wall between commercial agricultural production and rural community life, or between production research and the rural social sciences.

Beus and Dunlap (1990) say that disagreement over the proper relationship of humans and agriculture to the natural environment distinguishes today's alternative agriculture debate from past agrarian movements. However, our findings show that the Midwestern land-grant community regards the general goal of minimizing agriculture's degradation of the environment as an important aspect of sustainable agriculture. The disagreement is more over environmental strategies and tactics, such as which production technologies might enhance sustainability, and the amount of genetic diversity that ought to be maintained in commercial crops and livestock. On the other hand, these scientists appear to have resolved the questions of whether and under what circumstances ecological values might supersede production and efficiency goals, or else they are unwilling to negotiate answers to those questions. Our panel's selection of essential and inappropriate attribute statements suggests that LGU scientists disagree on the relative importance of the agrarian aspects of sustainability, but agrarian questions of structure, independence and community hold little appeal for most of them.

Although their vision of sustainable agriculture clearly is influenced by the alter-

native agriculture critique, the scientists envision a largely conventional version of sustainable technology research and development. The relative importance they accorded to retaining all production technologies and their support for agricultural research, coupled with the absence of statements regarding farmer-driven research and development, suggest that they are not sympathetic to calls for a more inclusive epistemology in agricultural research (Kloppenburg, 1991a; Flora, 1992). Consequently, we do not expect much increase in LGU support for or collaboration with farmer-directed efforts to evaluate alternative production technologies through on-farm research. The scientists appear willing to count environmental soundness and profitability as goals for agricultural research, but they also see sustainable agriculture as largely a technical problem whose solution will be found in conventional approaches to agricultural research. For most, the search for sustainability may mean "business as usual," a pursuit of production and efficiency goals, although with an environmental flavor.

In more practical terms, the delphi findings suggest there is considerable support across the agricultural sciences for research and development of environmentally sound farming technologies and systems. But the findings also suggest that there may be only weak support for research on how these technologies affect rural social and economic life and on which production systems might better maintain or enhance rural communities. Furthermore, interest in the community and agrarian aspects of alternative agriculture may have no clear home within any academic field at the LGUs. After surveying the views of agricultural faculty at one LGU, Beus and Dunlap (1992) concluded that only the social science disciplines (excluding agricultural economics) may be inclined to answer many questions posed by alternative agriculture proponents. We found little propensity among Midwestern crop and animal scientists or among agricultural economists, who constituted all but three of the social scientists on the panel, to regard community health, structural diversity and greater farmer independence as primary components of sustainability.

The scientist panel began with diverse individual conceptions of sustainable agriculture that included agrarian and structural critiques of conventional agriculture and more conventional concerns for productivity and environmental protection. The initial list of attributes also called for more attention to non-economic values in addition to more concrete technological needs. But when later rounds forced the panelists to focus on aspects of sustainability they consider more central, their environmental and technology-related concerns dominated. A large proportion focused on the environmental dimensions and technological needs of sustainability. This represents the "common ground" from which to build a broader consensus about what needs to be sustained. On the other hand, there is little consensus among scientists on what sustainability might entail beyond environmentally cleaner farming technologies.

The delphi process required the participants to focus their definition of sustainability; otherwise, they could have embraced definitions of the term that incorporated any number of consistent and inconsistent elements. Yet an analogous need to refine definitions arises when scientists propose objectives and allocate resources for sustainable agriculture research. Buttel and Gillespie (1988) argue that the term "sustainability" has been readily (and perhaps irreparably) appropriated by conventional commercial agriculture and agricultural research to defuse and coopt their agrarian and environmental critics. Many noneconomic values brought out by the debate over sustainability are supported in principle by many LGU agricultural scientists. However, our findings strongly suggest that when resources must be allocated among specific objectives, these values are likely to be sacrificed in favor of less radical arguments.

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References

1. Allen, P.L., and C.E. Sachs. 1991. The social side of sustainability: Class, gender and race. Science as Culture 2(4):569-590.
2. Berry, W. 1977. The Unsettling of America: Culture and Agriculture. Avon Books, New York.
3. Berry, W. 1984. Whose head is the farmer using? Who is using the farmer's head? In W. Jackson, W. Berry, and B. Colman (eds). Meeting the Expectations of the Land. North Point Press, San Francisco, California. pp. 19-30.
4. Beus, C.E., and R.E. Dunlap. 1990. Conventional versus alternative agriculture: The paradigmatic roots of the debate. Rural Sociology 55(4):590-616.
5. Beus, C.E., and R.E. Dunlap. 1991. Measuring adherence to alternative vs. conventional agricultural paradigms: A proposed scale. Rural Sociology 56(3):432-460.
6. Beus, C.E., and R.E. Dunlap. 1992. The alternative-conventional agriculture debate: Where do agricultural faculty stand? Rural Sociology 57(3):363-380.
7. Busch, L., and W.B. Lacy. 1983. Science, Agriculture, and the Politics of Research. Westview Press, Boulder, Colorado.
8. Buttel, F.H., and G.W. Gillespie. 1988. Agricultural research and development and the appropriation of progressive symbols: Some observations on the politics of ecological agriculture. Bull. 151. Dept. of Rural Sociology, Cornell Univ., Ithaca, New York.
9. Douglass, G. 1984. The meanings of agricultural sustainability. In G. Douglass (ed). Agricultural Sustainability in a Changing World Order. Westview Press, Boulder, Colorado. pp. 3-30.
10. Evenson, R.E., P.E. Wagoner, and V.W. Ruttan. 1979. Economic benefits from research: An example from agriculture. Science 205:1101-1107.
11. Flora, C.B. 1992. Reconstructing agriculture: The case for local knowledge. Rural Sociology 57(1):92-97.
12. Freudenberger, C. 1986. Value and ethical dimensions of alternative agricultural approaches: In quest of a regenerative and just agriculture. In K.A. Dahlberg (ed). New Directions for Agriculture and Agricultural Research. Rowman and Allenheld, Totowa, New Jersey. pp. 348-364.
13. Hadwiger, D.F. 1982. The Politics of Agricultural Research. Univ. of Nebraska Press, Lincoln.

14. Hamlin, C. 1991. Green meanings: What might "sustainable agriculture" sustain? Science as Culture 2(4):507-537.
15. Hightower, J. 1973. Hard Tomatoes, Hard Times. Schenkman Publishing Co., Cambridge, Massachusetts.
16. Jackson, W. 1984. A search for the unifying concept for sustainable agriculture. In W. Jackson, W. Berry, and B. Colman (eds). Meeting the Expectations of the Land. North Point Press, San Francisco, California. pp. 208-229.
17. Jackson, W. 1987. Altars of Unhewn Stone. North Point Press, San Francisco, California.
18. Kloppenburg, J.R., Jr. 1991a. Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. Rural Sociology 56(4):519-548.
19. Kloppenburg, J.R., Jr. 1991b. Alternative agriculture and the new biotechnologies. Science as Culture 2(4):482-506.
20. Levidow, L. 1991. Cleaning up on the farm. Science as Culture 2(4):538-568.
21. Linstone, H.A., and M. Turoff. 1975. The Delphi Method: Techniques and Applications. Addison-Wesley, Reading, Massachusetts.
22. MacRae, R.J., S.B. Hill, J. Henning, and G.R. Mehuys. 1989. Agricultural science and sustainable agriculture: A review of the existing scientific barriers to sustainable food production and potential solutions. Biological Agric. and Horticulture 6:173-219.
23. Molnar, J.J., P.A. Duffy, K.A. Cummins, and E. Van Santen. 1992. Agricultural science and agricultural counterculture: Paradigms in search of a future. Rural Sociology 57(1):83-91.
24. National Research Council. 1989. Alternative Agriculture. Board on Agriculture. National Academy Press, Washington, D.C.
25. Ruttan, V.W. 1982. Agricultural Research Policy. Univ. of Minnesota Press, Minneapolis.
26. Ruttan, V.W. 1987. Agricultural scientists as reluctant revolutionaries. Choices 2:3.

UPCOMING EVENTS

October 21 is the deadline for paper abstracts for *Versatility of Wetlands in the Agricultural Landscape*, to be held September 18-20, 1995, in Tampa, FL; contact George Vellidis, University of Georgia, Bio. & Agr. Eng. Dept., Coastal Plains Experiment Station, Tifton, GA 31793; (912)386-3377.

October 23-26, *Protecting Rural America's Water Resources: Partnerships for Pollution Solutions* will be held in Washington, D.C.; contact Ben Grunewald, Ground Water Protection Council, 827 NW 63rd St., #103, Oklahoma City, OK 73116; 1-800-762-0190.

October 29, *Annual Urban-Rural Day*, sponsored by Michael Fields Agricultural Institute, will be held in Pewaukee, WI; contact Gail Kahovic, MFAI, (414)642-3303.

November 4-5, *Second Annual Small Farm Today Seminar & Trade Show* will be held in Columbia, MO; contact Small Farm Today, 3903 W. Ridge Trail Rd., Clark, MO 65243; 1-800-633-2535.

November 4-6, *Sustainable Biointensive Mini-Farming* will be held in Willits, CA; contact Mary Campagna, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490; (707)459-0150.

November 5-6, *Fifth Annual Farmer to Farmer Conference* will be held in Bar Harbor, ME; contact Maine Organic Farmers and Gardeners Association, Box 2176, Augusta, ME 04338; (207)622-3118.

November 9-11, *Vision 2000: The Path to Sustainable Development* will be held in Baltimore, MD; contact Wildlife Habitat Council, 1010 Wayne Avenue, #920, Silver Spring, MD 20910; (301)588-8994.

November 10, *On and Off the Land: A Public Symposium to Examine Agriculture from Urban & Rural Perspectives* will be held in Portland, OR; contact David Milholland, Oregon Tilth, P.O. Box 3588, Portland, OR 97208; (503)285-8279.

November 11-13, *Telling the Story: Celebrating Tilth's First Twenty Years* will be held in Portland, OR; contact Tilth, P.O. Box 3588, Portland, OR 97208; (503)285-8279.

December 10-14, *10th International IFOAM (International Federation of Organic Agriculture Movements) Conference on Organic Agriculture* will be held at Lincoln University, Christchurch, New Zealand; contact Conference Secretariat, P.O. Box 84, Lincoln University, Christchurch, New Zealand; phone 64-3-325-3819; fax 64-3-325-3840.

Farm Profiles Invited

For its new department on alternative agriculture profiles, the *AJAA* welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the *AJAA* has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Identifying suitable regions for amaranth production using a geographic information systems approach

Robert L. Myers

Abstract. *Amaranth is an alternative grain crop that shows significant promise in the U.S. A geographic information system (GIS) was used to analyze the most suitable regions for growing amaranth in Missouri. GIS software provides tools to manipulate and display geographically based information, in this case the factors affecting amaranth's suitability. Of several such factors considered, the ones used were soils, rainfall, sorghum production, disease potential, and labor availability. Soil, rainfall, and disease information were assumed to be direct factors in yield potential. Current sorghum production areas were considered likely areas for amaranth production, given the similarities between the crops. Labor availability also was assumed to affect adoption, since amaranth requires more labor than traditional grain crops. The analysis showed that central and southeastern Missouri would be the most favorable areas for amaranth production. Other suitable areas are along the Mississippi and Missouri river valleys and in western Missouri. This GIS approach can be modified to include additional factors and refinements, and could be used with other alternative crops or for other regions of the country.*

Key words: alternative crops, crop selection factors

Introduction

Amaranth (*Amaranthus* spp.) is an alternative cereal grain and former Aztec crop that has received increased attention during the last two decades (Lehmann, 1990). Although production of amaranth has been widely distributed across the U.S., little effort has been made to identify different regions' suitability for amaranth production. The geographic information systems (GIS) approach is a way to relate geographically based information through computer tools (Bjerklie, 1989). I used the GIS approach to identify suitable regions for amaranth production in Missouri.

Amaranth is being evaluated as an alternative crop in Missouri for several reasons. The crop has been proven to be widely adaptable and able to perform well in row crop regions. Its relative drought tolerance is an asset for Missouri, since current grain crops in Missouri, particularly corn, often are limited by soil moisture late in the summer. Two major urban centers in Missouri provide possible outlets for amaranth as a food, and the substantial livestock industry in Missouri could use amaranth as a forage or feed crop. Agriculture in Missouri, as in most Midwestern states, is dominated by a few major commodity crops, and needs alternative crops that can allow more use of crop rotations and provide economic and ecological diversification.

Most factors that would affect whether amaranth is grown in an area also affect the selection of other crops. These include suitability of soil and climate, chance of pest problems, availability of needed equipment, access to storage, transportation and processing, and compatibility with current cropping systems. A producer who previously has worked with specialty crops or other contracted production may be more capable or comfortable with an alternative crop such as amaranth than one who takes commodity crops to the local elevator.

Specific climatic requirements of amaranth include a growing season long enough to allow the seed to mature before harvest, a dependable fall frost to help dry the plants before harvest, and warm soils at spring planting to allow good establishment (Myers and Putnam, 1988). Rainfall is needed for establishment but can be detrimental when amaranth is drying down or being harvested.

Since there are only a few main collection points for amaranth in the U.S. (none in Missouri), most of the grain is transported long distances by truck. Producers who grow traditional grain crops (corn, soybeans, sorghum or small grains) are more likely to have field equipment that can be used with amaranth than producers who do not. Since most pesticides cannot

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legally be used on amaranth, more management time and labor is likely to be needed for amaranth than for a comparable corn or soybean field.

GIS computer tools allow factors affecting selection of amaranth or other crops to be incorporated into a single database and handled in sophisticated ways. The simplest aspects of GIS analysis could be simulated by overlaying two maps on transparency sheets, such as one each for soils and rainfall, and looking for the intersections of areas that are ideal in both rainfall and soil type. This approach would work less effectively as the number of factors increased. More importantly, transparencies do not allow each factor to be weighted for its relative significance (Environmental Systems Research Institute, 1990). For example, soil type may be determined to be twice as important as rainfall, a relationship that can be handled easily by GIS software. GIS tools also allow for rapid testing of different combinations of crop selection factors and weighting schemes to incorporate each factor into the final suitability ratings. Another key characteristic of GIS software is that it allows maps to be generated from tabular data or digitized input.

GIS analysis has been used for many purposes, including street planning, locating schools, and making natural resource management decisions (Peuquet and Marble, 1990; Tomlinson, 1990). GIS analysis increasingly is being used in agricultural land management, such as a system that was developed to assess the relationship between land use and well water resources in Florida (Tan and Shih, 1990). In Tennessee, a GIS approach was used to identify regions most suitable for vegetable production (Brooker and Gray, 1990). Researchers in Montana have used GIS techniques to identify growing regions for several alternative crops, including amaranth (Nielsen et al., 1990). In the Montana project, a map was generated indicating areas of low, moderate, or high potential for amaranth based on soil and climatic information. Researchers have used this map to target research on amaranth and to help producers in evaluating amaranth for their region.

The objective of the amaranth GIS project reported here was to apply the technique to Missouri soil and climate conditions, and extend the use of the GIS database to incorporate other factors that could affect amaranth performance or adoption, such as current cropping patterns, chance of disease occurrence, and labor availability. The application of GIS analysis, like computer simulation modeling, involves continual improvements as new insights are gained. The amaranth suitability map generated in this research provides an initial assessment of the suitability of different regions of Missouri for amaranth, but can be improved upon as understanding of amaranth production and adoption improves.

Methods

A geographic database was constructed from various data sources using ARC/INFO software (Environmental Systems Research Institute, Redlands, California, version 5.0.1) on a Dec Station 5000 minicomputer. Data were compiled for the entire state of Missouri. A digitizing tablet was used to enter soil map information, township boundaries, and regional ratings of disease potential. The remaining data, including weather, cropping patterns, and labor supply, were entered in tabular format with geographic tags.

Ideally, soil information would be handled on the smallest unit area possible, such as the individual soil associations shown in county soil maps. Unfortunately, soil association maps have not yet been digitized into computer format in Missouri, since it is a very time-consuming process. For this project, I used more generalized soil maps. A Soil Conservation Service map of Missouri (U.S. Dept. of Agriculture, 1979) divides the state into ten general soil classification areas, a manageable number of area boundaries to digitize. The soil regions were rated from 1 to 4 in suitability for amaranth, with 1 the most suitable and 4 being unsuitable. Soil groups rated as 1 were Missouri/Mississippi Alluvium, and Deep Loess Hills. The Deep Loess and Drift, Central Claypan, Mississippi Delta and Cherokee Prairies areas were rated 2, while the Central Mississippi area was rated 3. The Ozark Border, Ozarks, and Ozark Dome areas, which have mostly unsuitable soils, all were rated 4.

Ratings of disease potential were generated by J. Mihail, a plant epidemiologist who has made considerable observations of amaranth for diseases in Missouri. Using field observations and information from the literature, she divided Missouri into five regions, and estimated the potential of each region as low, moderate or high for damping off (caused by *Rhizoctonia* spp. and *Pythium* spp.), stem rot (caused by *Choanephora cucurbitarum)*, white rust (caused by *Albugo blitum),* and nematodes. These regional estimates for these pathogens were aggregated and used to give each of the five regions a rating of 1 to 3, with 3 the most likely to have a disease problem.

Thirty-year averages of weekly temperature and rainfall were used from 80 weather recording stations around Missouri (data provided by the Atmospheric Science Department at University of Missouri). This large number of locations allowed isoclines to be generated representing temperature and rainfall gradients across the state. Dates of average first and last frost were also compiled in the database, but not used in the final analysis. Since it was unclear how temperature differences within the state might affect amaranth, only weekly rainfall data were used. Rainfall at the time of planting was determined to be unimportant, since my preliminary field research has shown that the planting date can vary by about a month without significantly affecting yield. This allows a producer to wait for suitable soil moisture conditions for planting. However, rainfall at harvest is more critical, since amaranth seed can begin shattering in a short time if harvest is delayed, and heavy rains can contribute to seed loss by shattering. Therefore, the rainfall during the most likely amaranth harvest period was used as a suitability factor. Weeks 29 to 32 of the calendar year were combined for 30 year rainfall average to identify regions of the state that differ in rainfall during the likely harvest period. Based on rainfall distribution for different regions of the state, a scale of 1 to 3 was chosen, with areas receiving less than 4.0 inches being rated 1, areas of 4.0 to 4.5 inches being rated 2, and areas of 4.5 inches or more being rated 3. (These divisions are somewhat arbitrary.)

Current cropping patterns were considered important in showing where the production environment for amaranth is favorable and where adoption is likely. Among the major summer annual grain crops in Missouri (corn, soybeans, and sorghum), sorghum was selected as the crop most similar to amaranth in its production requirements. Amaranth is planted about the same time as sorghum and harvested slightly later. Both are relatively drought tolerant and have moderate fertility needs. Both normally are planted in wide rows to allow cultivation, and both typically receive little or no pesticides (no pesticides currently are labeled for amaranth). I assumed that amaranth is more likely to substitute for sorghum than for other crops, because of its similar production requirements and the trend among Missouri producers to be less committed to sorghum than corn or soybeans.

To incorporate these assumptions about the substitution of amaranth for sorghum, data were compiled on the amount of sorghum in each county, expressed as a fraction of total row crop area to eliminate the size of a county as a confounding factor. I decided arbitrarily to give a rating of 1 (most suitable) to areas with more than 23% sorghum, 2 to areas with 15 to 23%, 3 to areas with 8 to 15%, and 4 to areas with less than 8%. Sorghum yield data were not used in the GIS database since it is not known how well amaranth yields correlate with sorghum yields.

I also assumed that amaranth is more likely to be adopted in areas with more intensive row crop production, since those farms would be more focused on improving their grain operations and would have a wider range of equipment available than in areas that primarily have pasture and livestock production. Total row crop area was used for each county, which biased the results toward larger counties. As a simple rating of row crop intensity, counties with more than 300,000 acres of row crops were rated 1, counties with 200,000 to 300,000 acres were rated 2, counties with 100,000 to 200,000 acres were rated 3, and counties with less than 100,000 acres were rated 4.

Adoption of amaranth could be affected by many factors other than agronomic and climatic considerations. Transportation, labor, experience with contract production, and even marketing ability could affect an individual producer's decision to grow amaranth. Of these, labor availability was considered worth analyzing here, since amaranth requires more labor than traditional commodity grains. The additional labor requirement begins with extra tillage to prepare a fine seedbed at planting, extra mechanical cultivation for weed control since no herbicides are available, and extra time at harvest to adjust harvesting equipment, clean the grain, and sometimes bag it for shipping. Labor availability in this situation is difficult to characterize accurately because data are not available on people with farm skills who are available for seasonal work. The only readily available data that could provide some insight on labor supply were on county unemployment (U.S. Dept. of Commerce, 1986). Suitability ratings were 1 through 4, with 1 being most suitable (most labor), using respective ranges of $\geq$7.22, 6.09 to 7.21, 5.36 to 6.09, and $\leq$5.36% unemployment in a county.

The final data handling step was to weight each factor according to its estimated relative importance. Soil suitability was weighted at 30%, with sorghum as a fraction of row crop area the next most important factor at 20%. Row crop area in a county and harvest rainfall each were weighted at 15%. Labor and disease potential were considered the least important factors, with both weighted at 10%. The ARC/INFO software generated new polygons through a vector-based approach to generate a suitability map using the weights for each factor.

Results

The map of different regions' suitability for amaranth is shown in Figure 1. The most suitable areas are concentrated in central Missouri and southeastern Missouri. Other suitable regions occur along the Missouri and Mississippi river valleys, and in western Missouri. Most of south central Missouri is rated as unsuitable because of the predominately rocky Ozark soils and lack of row crop production in that region.

The location of suitable sites in southeastern Missouri is a strong reflection of the concentrated sorghum production in that portion of the state and its favorable soils. The good suitability of central Missouri reflects both appropriate soils for amaranth and moderate levels of sorghum production.

Discussion

The GIS analysis of Missouri for amaranth production reported here represents an initial effort to determine the feasibility of this approach for targeting amaranth research and production sites. Refinements could be made to the factors currently incorporated, and additional factors affecting production or adoption could be added to this type of GIS analysis, as discussed below. However, this initial analysis did provide a useful way of logically relating quantitative, geographically based information in a way that allows the results to be visualized. Otherwise, it would be difficult to construct these geographic relationships, particularly if weighting is employed. The map generated for amaranth suitability currently is being used to assist in research planning and extension programming.

The limitations of GIS analysis are similar to those of computer simulation modeling, and additions and improvements always are possible. Production factors that could be refined in this analysis include rainfall patterns and changes in cropping patterns over time. Temperature information could be added if its impact on amaranth were better understood. Timing of fall frosts could be important, but we do not yet know what temperature will consistently kill amaranth in the fall. It would be helpful to correlate amaranth yields to sorghum yield in varying environments. If both crops showed a similar yield response to various soil and weather conditions, sorghum yield data could be effectively used in amaranth GIS studies. Pest factors could also be incorporated as they became better understood. An example is tarnished plant bug *(Lygus lineolaris),* a particularly troublesome pest of amaranth. Many weeds can compete with amaranth, but various pigweed species probably are the most serious because they are so closely related to grain amaranth.

Besides the factors that could influence the yield potential of amaranth in a given area, it is necessary to consider other fac-

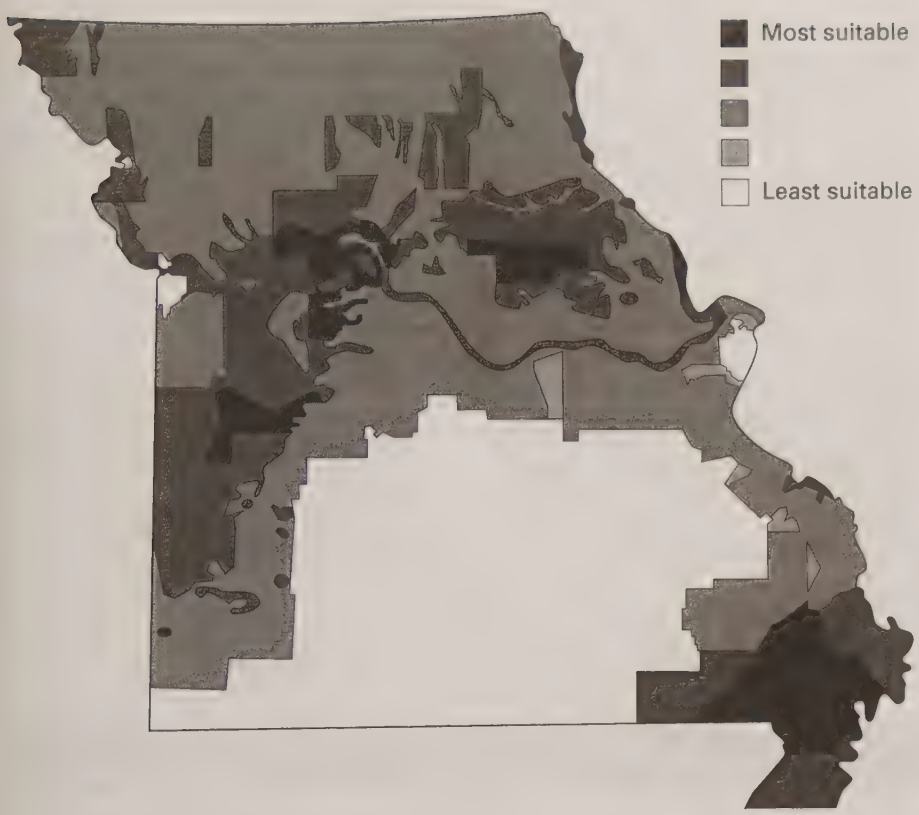

Figure 1. Map of Missouri showing the suitability of different regions in the state for amaranth production, based on soils, current crops, disease pressures, climate, and labor availability.

tors that might influence an individual farmer's decision on whether to adopt it. These include not only labor, which was incorporated into the present analysis, but also transportation, equipment availability, and farmers' experience with specialty crops and contract production. Labor was particularly difficult to incorporate into this analysis because available data do not reflect the type of skilled labor that would be needed seasonally. The unemployment figures I used give some indication of labor availability, but more specific data would be more valuable.

GIS tools can analyze transportation, but there is little reason to do so for amaranth production in Missouri. Anyone growing amaranth in Missouri would have to ship it out of state several hundred miles to one of the few current collection points, so that differences in transportation costs from various parts of the state are small. However, a grower who marketed amaranth directly to food processors or consumers might have an advantage by being close to urban centers in Missouri such as St. Louis or Kansas City.

The availability of appropriate equipment for amaranth and the producers' experience with specialty crops or contracts would be hard to assess geographically, since equipment and experience levels vary so much even within small areas. Of these two factors, grower experience level might show more of a geographic pattern. Further refinements in this amaranth GIS could involve looking for data on concentrated areas of producers who have successfully contracted with a local processor or marketer for a specialty crop.

A significant weakness of the GIS approach for analyzing areas to grow crops is that the suitability maps that can be generated are difficult to validate, other than by trying to make certain that key assumptions are logical and based on scientific observations and data. In particular, the process of weighting factors is arbitrary. The best way to validate this type of suitability map would be to plant several varieties of the crop on various soil types around the state, and to measure yield over several years to reduce the uncertainties of annual variation. However, such an expensive, time-consuming, long-term evaluation is what this use of GIS was intended to avoid. Unlike computer modeling, where a historical data set can be used to validate a model for predicting a future set of data, a GIS for alternative crops can undergo only minimal validation. Correlating amaranth with yield of sorghum or another major crop and then using the available data on that crop's performance would probably be the best way to strengthen this GIS.

In summary, GIS analysis is a powerful way of relating different kinds of site-specific data, in this case to generate a map showing the suitability of amaranth for different regions of Missouri. Although the initial GIS effort reported here could be improved, it has provided information that has been helpful for research and extension purposes. It serves as an alternative to a multi-site, multi-year field evaluation of amaranth potential in various parts of the state. However, it cannot have the same certainty as long-term field testing, and must be combined with some field testing. The techniques employed in this analysis could be adapted to other states, or even used nationwide for amaranth or other alternative crops. Overall, the flexibility, quantitative nature, and time and cost savings provided by GIS analysis make it a

useful approach for speeding the evaluation and development of alternative crops such as amaranth.

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References

1. Bjerklie, D. 1989. The electronic transformation of maps. Technology Review (Massachusetts Institute of Technology), April, pp. 54-62.
2. Brooker, J.R., and M.D. Gray. 1990. Identification of vegetable growing areas in Tennessee from computer-generated maps based on geographic information systems. Tennessee Farm and Home Science. No. 153 (Winter). Univ. of Tennessee Agric. Exp. Station, Knoxville. pp. 4-9.
3. Environmental Systems Research Institute. 1990. Understanding GIS: The ARC/INFO Method. Redlands, California.
4. Lehmann, J.W. 1990. Potential of grain amaranths in the 1990's and beyond. In Proceedings of the Fourth National Amaranth Symposium: Perspectives on Production, Processing, and Marketing, Minneapolis, Minnesota. pp. 1-17.
5. Myers, R.L., and D.H. Putnam. 1988. Growing grain amaranth as a specialty crop. AG-FS-3458. Univ. of Minnesota Extension Service, St. Paul.
6. Nielsen, G.A., J.M. Caprio, P.A. McDaniel, R.D. Snyder, and C. Montagne. 1990. MAPS: A GIS for land resource management in Montana. J. Soil and Water Conservation 45:450-453.
7. Peuquet, D.J., and D.F. Marble. 1990. ARC/INFO: An example of a contemporary geographic information system. In D.J. Peuquet and D.F. Marble (eds). Introductory Readings in Geographic Information Systems. Taylor and Francis, New York, N.Y. pp. 35-54.
8. Tan, Y.R., and S.F. Shih. 1990. GIS in monitoring agricultural land use changes and well assessment. Trans. Amer. Soc. Agric. Engineers 33:1147-1152.
9. Tomlinson, R.F. 1990. Geographic information systems — a new frontier. In D.J. Peuquet and D.F. Marble (eds). Introductory Readings in Geographic Information Systems. Taylor and Francis, New York, N.Y. pp. 112-136.
10. U.S. Dept. of Agriculture. 1979. Missouri general map and soil association descriptions. Soil Conservation Service, Columbia, Missouri.
11. U.S. Dept. of Commerce. 1986. City-County Data Book. Bureau of the Census, Washington, D.C.

LETTER

Uniform or farm-specific management in on-farm research?

The editorial by Lockeretz (*AJAA* 8(2):50,93) makes a point that we have been grappling with in our on-farm research with organic farmers in Nova Scotia: "We don't learn much from an experiment where the range of applicability is unknown or, even worse, where it might not extend at all beyond the specific circumstances under which the data were collected." In our work we see clearly the conflict between farmers' and researchers' objectives in on-farm research. As Gerber has commented (*AJAA* 7(3):118-121), scientists want a statistically valid experimental design and uniformity of nontreatment variables. They strive for statistically significant differences among treatments and try to minimize the interactions among experimental factors, especially location. Farmers, on the other hand, are most interested in experimental conditions that represent their farms, so that the results can be applied directly to their production system.

We attempted to minimize the variability among the four farms in our study by asking the farmers to plant oats two months before the experimental treatments were established. One farmer refused, arguing that this was something he does not normally do. This raises a serious question: Should we ask farmers to do something they would not normally do, for the sake of reducing variability? Reduced variability may make the results clearer and easier to interpret, but if the experiment does not represent the participating farm's current system, the farmer may not know if the results would have been the same had the usual practices been followed. Wouldn't the results of on-farm research be much more useful if farmers managed the experiment the way they manage the rest of the farm, except for the treatment variables? If a treatment produces consistent results that are independent of nontreatment management practices and location, this is a much more useful scientific finding. On the other hand, if the results vary among farms, the various management and environmental factors can be studied to understand better just what is going on. If we are trying to learn the range of applicability of an experiment, we should conduct it under the range of conditions normally found in the region.

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Screening cool-season legume cover crops for pecan orchards

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Abstract. *We evaluated selected cool-season annual and perennial legumes as potential ground covers to supply nitrogen and to increase beneficial arthropod populations in a pecan orchard. Densities of aphids (Homoptera: Aphididae), lady beetles (Coleoptera: Coccinellidae), damsel bug (Hemiptera: Nabidae), green lacewings (Neuroptera: Chrysopidae), brown lacewings (Neuroptera: Hemerobiidae), hover flies (Diptera: Syrphidae), spined soldier bug and other stink bugs (Hemiptera: Pentatomidae), and spiders (Araneida) were monitored at 7-14 day intervals during the growing season for three years. Aboveground biomass production and nitrogen content of the legumes was measured for two years. Aphids peaked during early spring each year, with the highest density usually on 'Dixie' crimson clover and 'Kenland' red clover. Density of lady beetles was positively correlated with that of aphids, but spider densities were not. Other arthropods usually were not abundant. Nitrogen in the tops of the annual legumes ranged from 20 kg/ha to 89 kg/ha when assessed after a single harvest at anthesis; for the perennial legumes it was from 108 kg/ha to 179 kg/ha following two harvests in June and September. We chose two annual legumes ('Dixie' crimson clover and hairy vetch) and two perennial legumes ('Louisiana S-1' white clover and 'Kenland' red clover) for further evaluation.*

Key words: aphid, Aphididae, Araneida, biological control, pecan, cover crops, Chrysopidae, Coccinellidae, Hemerobiidae, Insecta, Fabaceae, Nabidae, Pentatomidae, Syrphidae

Fertility and Pest Management of Pecan Orchards

Pecan (*Carya illinoinensis* [Wangenh.] C. Koch) is produced in two types of commercial orchards in the U.S. One type is based on wild trees (called natives) that have been cleared of competing vegetation and thinned periodically to the correct spacing for optimum production (Harris, 1983). Management of native orchards ranges from complete fertility and pest management programs to little management, with the trees harvested irregularly. From 1970 through 1990, native pecans accounted for 38% of production in the U.S., and 92% in Oklahoma (Napper, 1991). About 70% of the native pecan orchards in Oklahoma are combined with cattle grazing (Mitchell and Wright, 1991). This requires managers to minimize pesticide use and choose pesticides that are compatible with cattle grazing.

The second type of orchard is planted with a few improved cultivars. There are over a thousand pecan cultivars (Thompson and Young, 1985), but only about 40 are common in the U.S. (Thompson, 1990). The main cultivars are 'Stuart', 'Schley' and 'Desirable' in the Southeast, and 'Western Schley' and 'Wichita' in the West. In the central pecan belt, about 20 cultivars dominate. Cultivar orchards are not usually grazed, and the ground cover is a closely mowed grass sod. The lack of genetic diversity among trees in these plantings compared with native orchards and the more aggressive management has meant that frequent pesticide applications have been required. This has caused aphids (Dutcher and Htay, 1985) and mites (Boethel, 1981) to acquire resistance to pesticides. It also has caused outbreaks of secondary pests (Mizell, 1991) because natural enemies were eliminated, which in turn required additional pesticide applications.

Compared with perennial grass sod, legume and mixed legume-grass ground covers can be beneficial in both types of orchards, both for supplying N and for controlling pests. Legumes once were commonly grown as cover or green manure crops in orchards, until inexpensive synthetic N fertilizers became available during the 1940s and 1950s (Tedders, 1983). Interest in legumes has increased recently because of higher N costs, acquired pesticide resistance by certain insects (Boethel, 1981; Dutcher and Htay, 1985), and the need to avoid pesticide loading in the environment. Erdman (1967) reported estimates of N fixed by several legumes ranging from 57 to 207 kg/ha. Wood et al. (1983) reported that 'Amclo' arrowleaf clover (*Trifolium vesiculosum* Savi) added about 112 kg/ha N to the pecan orchard.

Another advantage of legume ground covers is that they can increase beneficial arthropods, which can aid in the control of aphids and other pests. Three aphid species attack pecan: yellow pecan aphid (*Monelliopsis pecanis* Bissell), blackmar-

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gined aphid (*Monellia caryella* [Fitch]), and black pecan aphid (*Melanocallis caryaefoliae* [Davis]) (Tedders et al., 1982). Yellow pecan aphid and blackmargined aphid cause damage to the foliage at the feeding site by clogging phloem, inducing chlorosis, irreversibly suppressing photosynthesis, and reducing nut size (Wood and Tedders, 1982; Wood et al., 1988). Feeding by black pecan aphids causes necrosis in the surrounding mesophyll cells and can cause premature leaf abscission (Lakin, 1972; Tedders et al., 1982). The pecan aphid complex is attacked by generalist predators and parasitoids (Edelson and Estes, 1987). Certain legumes harbor large populations of other prey aphids that tend to attract aphid predators and parasitoids. The alternative prey aphids common on legumes in the southern U.S. are blue alfalfa aphid (*Acyrthosiphon kondoi* Shimji), pea aphid (*Acyrthosiphon pisum* [Harris]), cowpea aphid (*Aphis craccivora* Koch), and yellow clover aphid (*Therioaphis trifolii* [Monell]) (Bugg et al., 1990). Aphids on legumes will not attack pecan; however, the predators and parasitoids that feed on them may also attack alternative prey aphids and other pests in the pecan trees.

Bugg et al. (1991b) proposed a cover crop management system to enhance beneficial arthropods in pecan orchards. Several cool-season and warm-season cover crops were evaluated in Georgia and Massachusetts to increase aphidophagous insects and other entomophaga to enhance biological control in vegetables and pecan (Wood et al., 1983; Bugg and Dutcher, 1989; Bugg and Ellis, 1990; Bugg et al., 1990, 1991a; Bugg and Dutcher, 1993). Among several potential cool-season crops screened, certain legumes were promising candidates to increase beneficial arthropods.

This study was undertaken to evaluate several cool-season annual and perennial legumes as potential ground covers in pecan orchards. The primary characteristics we evaluated were their ability to attract beneficial insects into the orchard and supply N.

Materials and Methods

Orchard site and management

We conducted the study in a commercial native pecan orchard near Sapulpa, in central Oklahoma. The soil was a Port loam (fine-silty, mixed, thermic; Cumulic Haplustoll; Mollisols), a deep, well drained, nearly level soil with high available water capacity. These soils occur on bottomland, and are typical soils for pecan production in this region.

In 1991 and 1992, *Bacillus thuringiensis* var. *kurstaki* was applied during early June against first generation pecan nut casebearer (*Acrobasis nuxvorella* Neunzig, Lepidoptera: Pyralidae). In 1993, chlorpyrifos was applied on April 21 and May 3 against phylloxera (*Phylloxera notabilis* Pergande, *P. russelae* Stoetzel, and *P. devastatrix* Pergande, Homoptera: Phylloxeridae), and on June 17 against pecan nut casebearer. Carbaryl was applied to control pecan weevil (*Curculio caryae* [Horn], Coleoptera: Curculionidae) on August 18, September 7 and 27, 1991, on September 15 and October 1, 1992, and on August 28 and September 15, 1993. No other insecticides were used.

Experimental design and analysis

Existing vegetation was killed during August 1990 with glyphosate. The soil was cultivated with a rotary tiller in late September. Legume seeds were inoculated with the appropriate commercial *Rhizobium* culture and distributed with a broadcast planter. The area then was packed with a roller. Perennial legumes were established once during 1990; the annual legumes were reseeded in September of each year. Seeding rates for each legume are listed in Table 1. In 1992, 'Yuchi' arrowleaf clover, rose clover, hairy vetch and 'Mt. Barker' subterranean clover were not included in the trial, and in 1993, rose clover, hairy vetch and 'Mt. Barker' subterranean clover were not included. A plot consisted of a single tree with the legume extending about 50% beyond the drip-line on all sides of the tree (plot sizes were about 1000 m^2). Each legume plot was replicated three times in a completely randomized design. Data were analyzed using analysis of variance with mean separation by Fisher's protected LSD or Duncan's multiple range test.

We sampled arthropod densities in 1991 through 1993 at 7 to 14 day intervals using a 38-cm diameter sweep net. Each sweep net sample consisted of ten sweeps per plot. The collected samples were transferred to plastic bags with pesticide impregnated strips (S.C. Johnson, Inc., Racine, Wisconsin), transported to the laboratory, and frozen until the arthropods of interest could be identified and counted. We monitored the following arthropods: aphids (Homoptera: Aphididae); lady beetles (*Hippodamia convergens* Guerin-Meneville, *Coccinella septempunctata* L., *Coleomegilla maculata lengi* Timberlake, *Cycloneda munda* [Say], Coleoptera: Coccinellidae); damsel bug (*Nabis* spp., Hemiptera: Nabidae); green lacewings (*Chrysopa* and *Chrysoperla* spp., Neurop-

Table 1. Legume names and seeding rates.

Legume	Scientific name	Seeding rate (kg/ha)
Annuals		
'Yuchi' arrowleaf clover	*Trifolium vesiculosum* Savi	9.1
'Dixie' crimson clover	*T. incarnatum* L.	18.3
Rose clover	*T. hirtum* All.	9.1
'Mt. Barker' subterranean clover	*T. subterraneum* L.	9.1
Hairy vetch	*Vicia villosa* Roth.	18.3
Perennials		
'Kenland' red clover	*T. pratense* L.	9.1
'Osceola' white clover	*T. repens* L.	3.7
'Regal' white clover	*T. repens* L.	3.7
'Louisiana S-1' white clover	*T. repens* L.	3.7

tera: Chrysopidae); brown lacewings (Neuroptera: Hemerobiidae); hover flies (Diptera: Syrphidae); spined soldier bug (*Podisus maculiventris* [Say], Hemiptera: Pentatomidae); stink bugs (Hemiptera: Pentatomidae); and spiders (Araneida). For aphids, we separated alatae (winged) from apterae (wingless) plus nymphs to determine trends during the growing season. We counted lady beetle adults by species, but we pooled larvae across species. For green lacewings, brown lacewings, and hover flies, we counted both larvae and adults, but we did not distinguish between adults and nymphs of spined soldier bug or stink bugs. On April 19, 1991 and April 23, 1993, we identified aphids by species, and calculated the population percentage of each species.

In 1991, we harvested two 1-m^2 legume biomass samples (tops only) from each plot at the edge of the tree canopy. The legumes were harvested once at the beginning of anthesis. In 1992, we harvested the annual legumes once at anthesis and the perennial legumes twice (during June and September, which coincided with mowing the rest of the plot). The samples were sorted into legumes and non-legumes (primarily grasses), oven-dried at 70°C, and weighed. The legumes were analyzed for N using the macro-Kjeldahl procedure (Horowitz, 1980), with total N in the tops calculated from the dry weight of the legumes in each sample and the N concentration in the legume tops.

Results

Arthropod populations

Aphids. Aphid density during 1991 peaked during late April and early May, then declined with the onset of frequent rainfall (Fig. 1A). 'Dixie' crimson clover had completed flowering, and the plants were senescing by May 14. Peak aphid density was greatest on 'Dixie' crimson clover and 'Yuchi' arrowleaf clover, followed by 'Kenland' red clover and 'Mt. Barker' subterranean clover, and least on rose clover and the three white clover cultivars. Aphids on hairy vetch were low until an increase on May 14, which coincided with the onset of flowering. However, on the next sampling date (May 29) no aphids were collected from hairy vetch or the other legumes. In 1991, alatae never exceeded 9% of the total aphids (Fig. 1B).

In 1992, variations in aphid densities were associated with rainfall patterns. Rainfall was infrequent during early spring, and the first two samples (April 14 and 21) yielded the highest aphid densities (Fig. 2A). There were more aphids on 'Dixie' crimson clover and 'Kenland' red

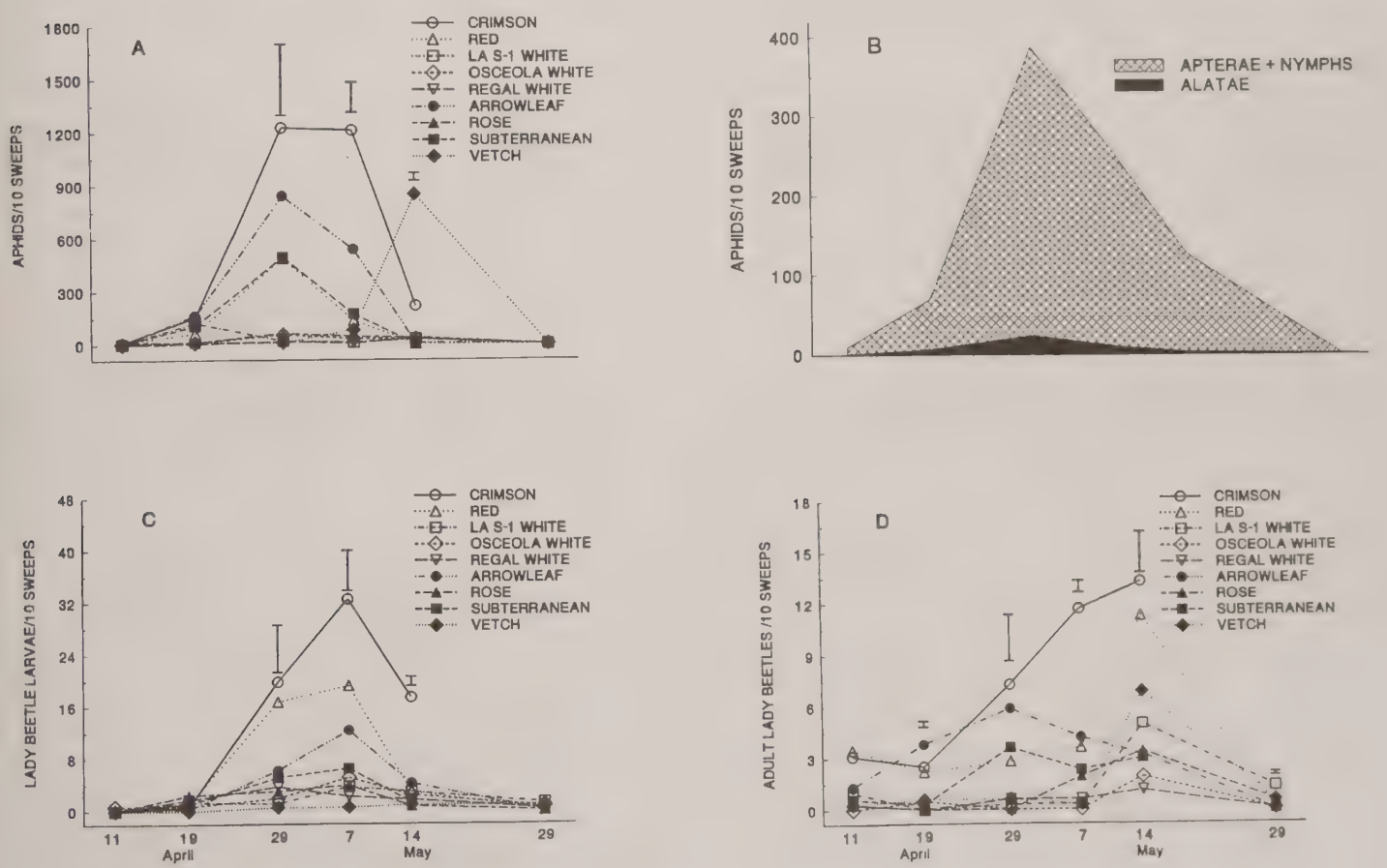

Fig. 1. Densities in 1991 of aphids on legume ground covers (A), alatae and apterae plus nymphs averaged over legume ground covers (B), lady beetle larvae on legume ground covers (C), and lady beetle adults on legume ground covers (D). Vertical bars represent Fisher's protected LSD value ($p<.05$).

clover than on the other legumes. Frequent rainfall began about May 1 and continued until late June. Aphids were low on legumes from May through mid-September, then increased on the perennial legumes on September 28. Alatae rose to 18% of the total aphids during April, were near zero through the rest of summer, then reached 18% of the total aphids again during late September (Fig. 2B).

In 1993, the aphid densities were erratic (Fig. 3A). For instance, on crimson clover the initial sample on April 8 showed a medium aphid density followed by a sharp decline, then an increase. Chlorpyrifos was applied to the pecan trees for phylloxera control on April 21 and May 3, 1993, which accounts for the sudden decrease in aphid density. During the previous two years, no insecticide applications were necessary during the early season. Aphid densities were highest during the spring, but were low or zero throughout the summer, in agreement with observations the previous two years. Alatae were a maximum of 17% of the total aphids present (May 22) (Fig. 3B).

Aphid species identified on the legumes were blue alfalfa aphid, pea aphid and cowpea aphid. In 1991 blue alfalfa aphid was

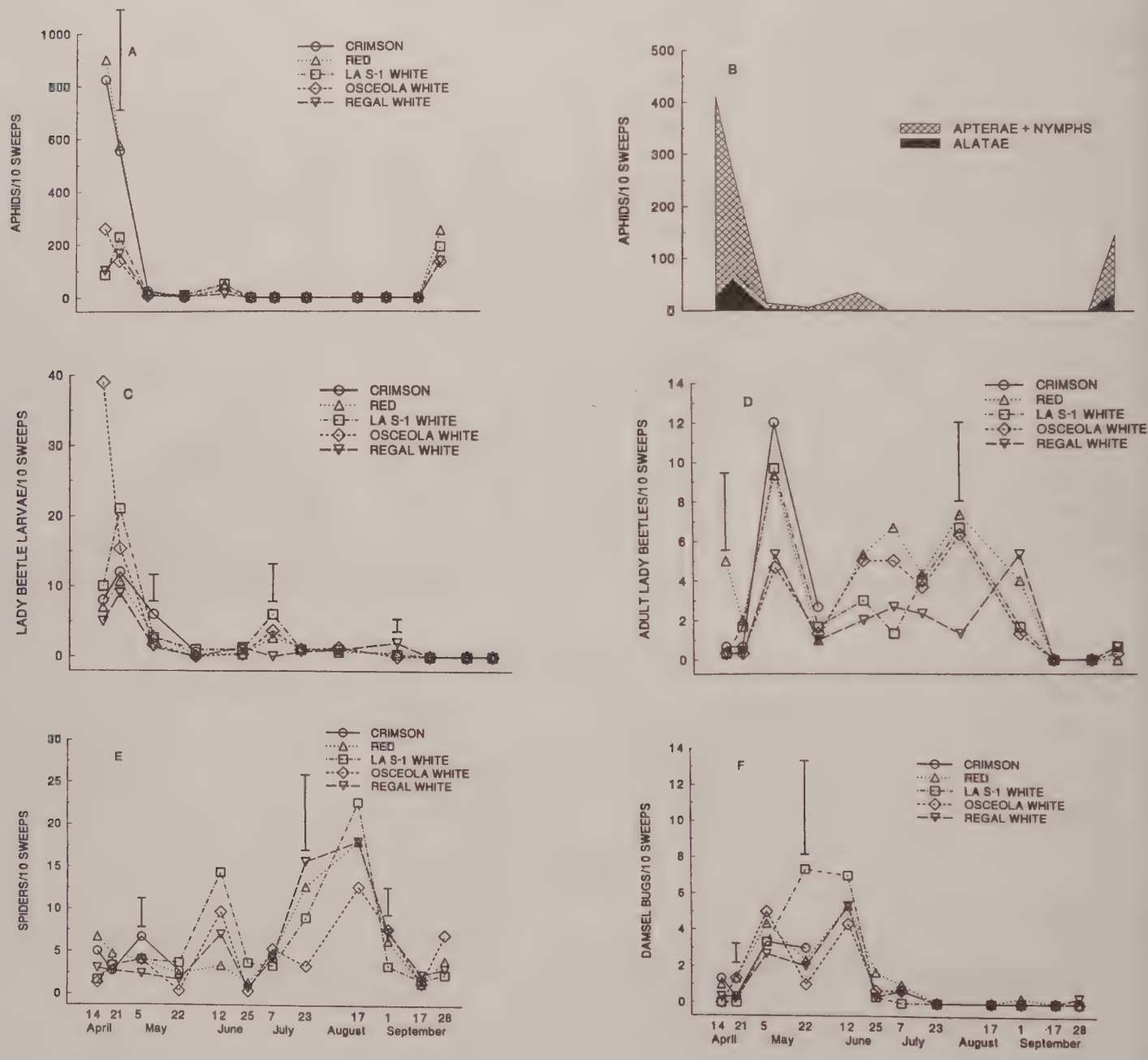

Fig. 2. Densities in 1992 of aphids on legume ground covers (A), alatae and apterae plus nymphs averaged over legume ground covers (B), lady beetle larvae on legume covers (C), lady beetle adults on legume ground covers (D), spiders on legume ground covers (E), and damsel bug on legume ground covers (F). Vertical bars represent Fisher's protected LSD value ($p<.05$).

the dominant species on 'Yuchi' arrowleaf clover, 'Mt. Barker' subterranean clover, and 'Kenland' red clover (Table 2). 'Dixie' crimson clover and 'Osceola' white clover had similar densities of blue alfalfa aphid and pea aphid. Pea aphid was the dominant species on rose clover, hairy vetch, 'Regal' white clover and 'Louisiana S-1' white clover. Although cowpea aphid was not the dominant species on any legume, three legumes (rose clover, hairy vetch, and 'Regal' white clover) had more cowpea aphids than the other legumes. In 1993, pea aphid was the dominant species on the legumes evaluated, although 'Kenland' red clover had many blue alfalfa aphids.

Lady beetles. The density of lady beetle larvae in 1991 peaked during late April and early May, then declined (Fig. 1C). This trend was strongly correlated with aphid trends (Table 3). The greatest lady beetle larval density was on 'Dixie' crimson clover, followed by 'Kenland' red clover (Fig. 1C). There were few differences in the number of lady beetle larvae in the other legumes.

In 1991, the density of adult lady beetles generally rose from early April until mid-May, then declined abruptly (Fig. 1D). Adult lady beetles were strongly correlated with aphid density (Table 3). As the number of lady beetles increased during late

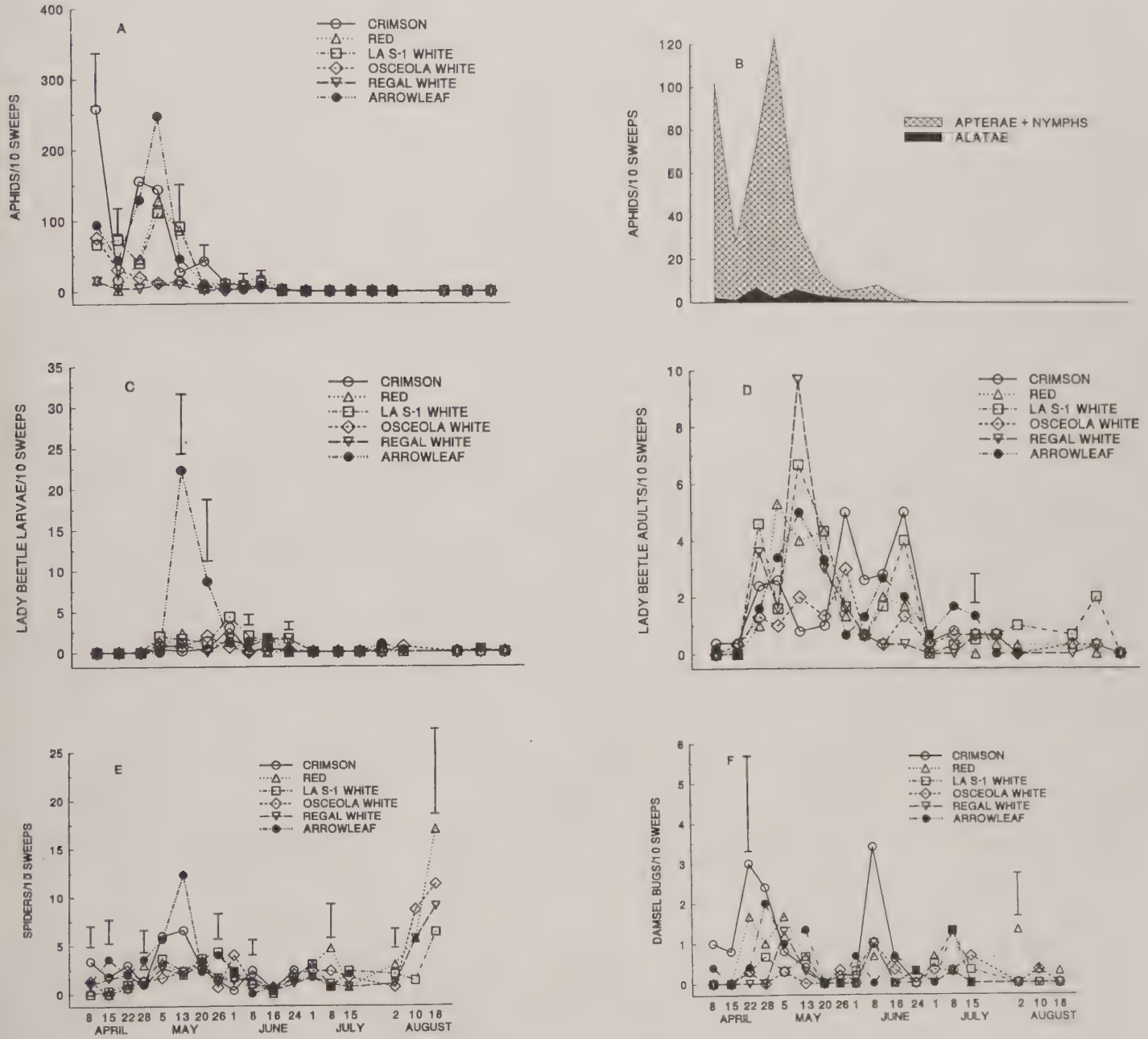

Fig. 3. Densities in 1993 of aphids on legume ground covers (A), alatae and apterae plus nymphs averaged over legume ground covers (B), lady beetle larvae on legume covers (C), lady beetle adults on legume ground covers (D), spiders on legume ground covers (E), and damsel bug on legume ground covers (F). Vertical bars represent Fisher's protected LSD value ($p<.05$).

Table 2. Influence of legume on aphid species in 1991 and 1993.

Legume	Aphid Species (%)		
	Blue alfalfa aphid	Pea aphid	Cowpea aphid
	April 19, 1991		
'Yuchi' arrowleaf clover	94.8	9.4	0.8
'Dixie' crimson clover	51.5	48.3	0.2
Rose clover	4.9	73.0	22.0
'Mt. Barker' subterranean clover	62.3	36.0	1.7
Hairy vetch	8.8	73.5	17.7
'Kenland' red clover	92.6	6.9	0.5
'Osceola' white clover	53.0	40.4	6.5
'Regal' white clover	19.0	63.5	17.5
'Louisiana S-1' white clover	6.7	91.3	2.0
	April 21, 1993		
'Dixie' crimson clover	0.5	99.0	0.5
'Kenland' red clover	16.3	82.9	0.8
'Osceola' white clover	1.8	96.5	1.7
'Regal' white clover	0.0	100.0	0.0
'Louisiana S-1' white clover	8.4	90.8	0.8

April and May, their density on 'Dixie' crimson clover was consistently among the highest (Fig. 1D). Other legumes that occasionally had abundant adult lady beetles were 'Kenland' red clover, 'Yuchi' arrowleaf clover, and hairy vetch. Other legumes had either intermediate or low densities. *Hippodamia convergens* (72%) was the dominant species in 1991, followed by *Cycloneda munda* (15%), *Coccinella septempunctata* (10%), and *Coleomegilla maculata lengi* (3%). We did not detect any differences among legumes in the species composition of lady beetles (data not shown).

In 1992, the lady beetle larval density was high during April, then declined sharply in May and remained low through September (Fig. 2C). This trend was weakly correlated with aphid densities (Table 3). There were few differences in densities of lady beetle larvae among the legumes in 1992. There was a clear peak in adult lady beetles on May 4, then a second peak during mid-June through late July (Fig. 2D). However, there were few aphids present or other arthropods that might serve as a food source, and we observed little egg laying. The species distribution was very different between 1991 and 1992. *Coleomegilla maculata lengi* accounted for 58% of the lady beetles collected, followed by *Coccinella septempunctata* (24%), *Hippodamia convergens* (12%), and *Cycloneda munda* (6%). In 1990, in contrast, *Hippodamia convergens* was the dominant species (72%), with *Coleomegilla maculata lengi* making up only 3% of the lady beetles.

In 1993, we observed few lady beetle larvae on the legumes, except on 'Yuchi' arrowleaf clover sampled on May 5 (Fig. 3C). The lower aphid density than the previous two years and the early-season chlorpyrifos application probably account for the reduced density of lady beetle larvae. The density of adult lady beetles was similar to that of 1992. The population peaked from early May through early June (Fig. 3D). Few significant differences in the number of lady beetles were observed among legumes. Species distribution was similar to 1992, with 68% being *Coleomegilla maculata lengi*, followed by *Hippodamia convergens* (16%), *Coccinella septempunctata* (10%) and *Cycloneda munda* (6%).

Spiders. In 1992, the density of spiders peaked during August (Fig. 2E). This trend was not associated with aphid densities (Table 3). Similarly, spider density in 1993 was low during spring and early summer, then peaked during August when aphid densities were low (Fig. 3E). Spiders are general predators, and their feeding activity was associated with arthropods other than aphids. Although there were some significant differences in spider density among the legumes, these differences were neither large nor consistent.

Other species. Damsel bugs were infrequent in 1991, and there were no significant differences among the legumes (data not shown). In 1992, damsel bug density peaked (Fig. 2F) immediately after the aphids crashed (Fig. 2A). Damsel bug density was low and erratic in 1993 (Fig. 3F), peaking on most legumes during late April. During 1991-93, there were few significant differences among the legumes in damsel bug density.

We collected green lacewings, brown lacewings, hover flies, and spined soldier bugs each year in the legume plots. However, these species were not abundant, and

Table 3. Correlations of aphid densities with lady beetle adults and larvae, spiders, and damsel bug.[1]

Lady Beetles			
Adults	Larvae	Spiders	Damsel bug
	1991		
0.58***	0.60***	0.36***	—
	1992		
-0.13NS	0.26*	0.10NS	-0.30*

[1] Correlations in 1991 contained 159 observations: 8 legumes by 3 replications by 6 dates, plus 1 legume by 3 replications by 5 dates. Correlations in 1992 contained 156 observations: 4 legumes by 3 replications by 12 dates plus 1 legume by 3 replications by 4 dates.

NS = non-significant; * = significant at p.<05; *** = significant at p.<001.

we did not see consistent trends or differences among the legumes (data not shown).

There were few stink bugs (peak population each year was 1 stink bug/10 sweeps) on all legumes in all three years. There were no consistent trends or differences among the legumes.

N in legume tops

Legume biomass from a single harvest in 1991 was greater for 'Yuchi' arrowleaf clover, 'Dixie' crimson clover, rose clover and 'Kenland' red clover than for the other legumes (Table 4). These legumes also tended to have the least non-legume biomass. In 1992, when the four perennial legumes were harvested twice, 'Kenland' red clover and 'Louisiana S-1' white clover produced more biomass than the other legumes. There were no significant differences in either non-legume or total biomass production in 1992.

In 1991, N concentration in legume tops ranged from 2.22% in rose clover to 3.61% in 'Regal' white clover. The three white clover cultivars had higher N concentrations than 'Yuchi' arrowleaf clover, 'Dixie' crimson clover, rose clover, or 'Mt. Barker' subterranean clover. Hairy vetch and 'Kenland' red clover were intermediate. In 1992, the three white clover cultivars ranged from 3.6% to 3.8% N during the first harvest and 3.3% to 3.6% during the second harvest. N concentration was higher in the white clover cultivars than in the other legumes during the first harvest, but there were no significant differences in N concentration among the legumes during the second harvest.

A single harvest of legume tops in 1991 ranged from 20 kg/ha N in 'Mt. Barker' subterranean clover to 82 kg/ha N in 'Dixie' crimson clover. In 1992, annual legumes were harvested once at anthesis, and perennial legumes were harvested twice to coincide with mowing. Total N in the legume tops ranged from 89 kg/ha N for 'Dixie' crimson clover to 179 kg/ha N for 'Kenland' red clover. 'Kenland' red clover and 'Louisiana S-1' white clover produced more N in the tops than the other legumes evaluated in 1992.

Conclusions

We chose four legumes for further evaluation in large plots. These are the perennials 'Kenland' red clover and 'Louisiana S-1' white clover and the annuals 'Dixie' crimson clover and hairy vetch.

Each legume chosen has certain strengths and weaknesses. 'Kenland' red clover was among the highest in N production and in attracting certain beneficial arthropods. However, the stands began to decline during the third year. Also, pure stands of red clover may compete excessively with the trees for water. 'Louisiana S-1' white clover was the best adapted of the three white clover cultivars evaluated. It produced a large amount of N but attracted few beneficial arthropods. 'Louisiana S-1' was aggressive, with the stands improving each year. 'Louisiana S-1' becomes relatively quiescent during the summer, thus minimizing competition for water, and provides an excellent harvest surface during the fall. Therefore, we chose these two perennial legumes for

Table 4. Biomass, N concentration and total N in the tops of selected legumes harvested once at anthesis during May or June, 1991 or harvested twice during May or June and September, 1992.

	Dry wt. (kg/ha)		May/June		September		Total N in tops
Legume	Non-legume	Legume	N conc. (%)	N in tops (kg/ha)	N conc. (%)	N in tops (kg/ha)	(kg/ha)
				1991			
'Yuchi' arrowleaf clover	4104a[1]	994bc	2.43c	80a	—	—	—
'Dixie' crimson clover	4135a	442c	2.54c	82a	—	—	—
Rose clover	3799a	1426abc	2.22c	65ab	—	—	—
'Mt. Barker' subterranean clover	732c	787bc	2.45c	20c	—	—	—
Hairy vetch	2285b	879bc	2.92abc	75a	—	—	—
'Kenland' red clover	3475a	1497abc	2.78bc	82a	—	—	—
'Osceola' white clover	1108c	3354b	3.47ab	34c	—	—	—
'Regal' white clover	1498bc	2903a	3.61a	44bc	—	—	—
'Louisiana S-1' white clover	1790bc	1430abc	3.46ab	52ab	—	—	—
				1992			
'Dixie' crimson clover	3445b	1742a	2.59b	89ab	—	—	89b
'Kenland' red clover	5745a[2]	928a	2.86b	104a	3.49a	75a	179a
'Osceola' white clover	2593b	2290a	3.71a	61b	3.48a	52ab	113b
'Regal' white clover	2712b	2209a	3.77a	58b	3.61a	42b	100b
'Louisiana S-1' white clover	4634a	800a	3.61a	90ab	3.29a	70ab	160a

[1] Mean separation within columns by Duncan's multiple range test ($p<.05$).
[2] Total biomass from two harvests.

planting as a mixture in large plots for further evaluation.

'Dixie' crimson clover consistently had larger aphid densities and attracted more beneficial arthropods than the other legumes evaluated. Similarly, Bugg et al. (1990) reported that crimson clover supported abundant coccinellids. 'Dixie' crimson clover also produced a large amount of N. Its major disadvantage is that plants mature and senesce while the trees are foliating, a time when there usually are few arthropod pests in the tree canopy. Planting crimson clover with another annual legume may extend the time that the ground cover will hold beneficial arthropods in the orchard. Bugg et al. (1990) reported that coccinellids were successively abundant on certain cover crops. The seasonal abundance of coccinellids was closely related to the presence of aphids or thrips on the ground covers. They suggested a polyculture of various ground covers to provide a seasonal sequence of foods to aphidophaga.

We observed that hairy vetch began rapid growth about the time crimson clover declined. Others have reported that hairy vetch was superior in harboring aphids or attracting coccinellids (Bugg and Ellis, 1990; Bugg et al., 1990; Bugg et al., 1991a). Aphid density on hairy vetch peaked after aphids on crimson clover had declined, thus extending the availability of foods for aphidophaga. Hairy vetch usually senesces when the density of pecan aphids is starting to increase, which encourages them to migrate into the canopy in search of prey. Therefore, a mixture of crimson clover and hairy vetch could be used to increase beneficial arthropods in the orchard and to get them to prey on pecan aphids.

References

1. Boethel, D.J. 1981. Resistance in the pecan leaf scorch mite, *Eotetranychus hicoriae* (McGregor) (Acari: Tetranychidae): Implications in pecan pest management. Misc. Pub. Entomology Soc. of Amer. 12:31-44.
2. Bugg, R.L., and J.D. Dutcher. 1989. Warm-season cover crops for pecan orchards: Horticultural and entomological implications. Biological Agric. and Horticulture 6:123-148.
3. Bugg, R.L., and J.D. Dutcher. 1993. *Sesbania exaltata* (Rafinesque-Schmaltz) Cory (Fabaceae) as a warm-season cover crop in pecan orchards: Effects on aphidophagous coccinellidae and pecan aphids. Biological Agric. and Horticulture 9:215-229.
4. Bugg, R.L., and R.T. Ellis. 1990. Insects associated with cover crops in Massachusetts. Biological Agric. and Horticulture 7:47-68.
5. Bugg, R.L., S.C. Phatak, and J.D. Dutcher. 1990. Insects associated with cool-season cover crops in southern Georgia: Implications for pest control in truck-farm and pecan agroecosystems. Biological Agric. and Horticulture 7:17-45.
6. Bugg, R.L., J.D. Dutcher, and P.J. McNiell. 1991a. Cool-season cover crops in the pecan orchard understory: Effects on coccinellidae (Coleoptera) and pecan aphids (Homoptera: Aphididae). Biological Control 1:8-15.
7. Bugg, R.L., M. Sarrantonio, J.D. Dutcher, and S.C. Phatak. 1991b. Understory cover crops in pecan orchards: Possible management systems. Amer. J. Alternative Agric. 6:50-62.
8. Dutcher, J.D., and U.T. Htay. 1985. Resurgence and insecticide resistance problems in pecan aphid management. In W.W. Neel, W.L. Tedders, and J.D. Dutcher (eds). Aphids and Phylloxeras of Pecan. Spec. Pub. 38. Univ. of Georgia Experiment Station, Athens. pp. 17-29.
9. Edelson, J.V., and P.M. Estes. 1987. Seasonal abundance and distribution of predators and parasites associated with *Monelliopsis pecanis* Bissell and *Monellia caryella* (Fitch) (Homoptera: Aphidae). J. Entomological Sci. 22:336-347.
10. Erdman, L.W. 1967. Legume inoculation: What it is, what it does. Farmers Bulletin No. 2003. Agricultural Research Service, U.S. Dept. of Agric., Washington, D.C.
11. Harris, M.K. 1983. Integrated pest management of pecans. Annual Review of Entomology 28:291-318.
12. Horowitz, W. 1980. Fertilizers. In S. Williams (ed). Official Methods of Analysis of the Association of Analytical Chemists. 13th ed. Assoc. of Official Analytical Chemists, Washington, D.C. p. 15, Sec. 205.
13. Lakin, K.R. 1972. An investigation of the damage associated with *Tinocallis caryaefoliae* (Davis) feeding on pecan leaves. Masters Thesis, Dept. of Entomology, Auburn University, Auburn, Alabama.
14. Mitchell, R.L., and J.C. Wright. 1991. Experiences in pecan orchard floor vegetation management: Two years of stocker steer performance and evaluation of grazing management. Annual Rep. of the Northern Nut Growers' Assoc. 82:72-79.
15. Mizell, R.F. III. 1991. Pesticides and beneficial insects: Application of current knowledge and future needs. In B.W. Wood and J.A. Payne (eds). Pecan Husbandry: Challenges and Opportunities. First National Pecan Workshop Proceedings. ARS-96. Agric. Research Service, U.S. Dept. of Agric., Springfield, Virginia. pp. 47-54.
16. Napper, W.P. 1991. Fruit and tree nuts situation and outlook report yearbook. TFS-258. Economic Research Service, U.S. Dept. of Agric., Washington, D.C.
17. Tedders, W.L. 1983. Insect management in deciduous orchard ecosystems: Habitat manipulation. Environmental Management 7:29-34.
18. Tedders, W.L., B.W. Wood, and J.W. Snow. 1982. Effects of feeding by *Monelliopsis nigropunctata, Monellia caryella,* and *Melanocallis caryaefoliae* on growth of pecan seedlings in the greenhouse. J. Economic Entomology 75:287-291.
19. Thompson, T.E. 1990. Pecan cultivars: Current use and recommendations. Pecan South 24(1):12-17, 20.
20. Thompson, T.E., and F. Young. 1985. Pecan cultivars - past and present. Texas Pecan Growers Assoc., Inc., College Station, Texas.
21. Wood, B.W., and W.L. Tedders. 1982. Effects of an infestation of blackmargined aphid on carbohydrates in mature 'Stuart' pecan. HortScience 17:236-238.
22. Wood, B., W. White, and W.L. Tedders. 1983. Use of legumes in pecan orchards. Annual Rep. of the Northern Nut Growers' Assoc. 74:147-150.
23. Wood, B.W., W.L. Tedders, and C.C. Reilly. 1988. Sooty mold fungus on pecan foliage suppresses light penetration and net photosynthesis. HortScience 23:851-853.

RESOURCES

1993 National Organic Farmers' Survey by the Organic Farming Research Foundation is $5 from OFRF, P.O. Box 440, Santa Cruz, CA 95061, or call Bob Scowcroft, (408)426-6606.

Proceedings of the National Integrated Pest Management Forum, held in June, 1992, by EPA and USDA, are available for $10 from American Farmland Trust, Center for Agriculture in the Environment, P.O. Box 987, DeKalb, IL 60115; (815)753-9347.

Biological Control of Insects and Mites: An Introduction to Beneficial Natural Enemies and Their Use in Pest Management, ($11 + $1.25 shipping); *Biological Control of Insect Pests of Cabbage and Other Crucifers*, ($8 + $1.25 shipping); and *Direct Marketing of Farm Produce and Home Goods*, ($3.50 + $1.05 shipping) are available from Cooperative Extension Publications, Room 245, 30 North Murray Street, Madison, WI 53715; (608)262-3346.

Sustainability: The Quiet Revolution, (VH-6349-NR1), a 45-minute video, is $45 from Distribution Center, Minnesota Extension Service, 20 Coffey Hall, St. Paul, MN 55108-6069; (612)625-8173 for credit card orders.

Integrated Pest Management: The Path of a Paradigm, by James Cate and Maureen Hinkle, 39 pages, is available for $5 from National Audubon Society, 666 Pennsylvania Ave., SE, #200, Washington, D.C. 20003; (202)547-9009.

Livestock for a Small Earth: The Role of Animals in a Just and Sustainable World, 111 pages, is $10 from Heifer Project International, 1015 S. Louisiana St., Little Rock, AR 72202.

Protecting Groundwater Quality in Citrus Production, #21521, is $5 from ANR Publications, University of California, 6701 San Pablo Ave., Oakland, CA 94608; (510)642-2431.

Greenbook '94, about the sustainable agriculture on-farm demonstration grant program, is available from Wayne Monsen, Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture, 90 West Plato Boulevard, St. Paul, MN 55107; (612)296-7673.

An Agriculture That Makes Sense: Profitability of Four Sustainable Farms in Minnesota, a joint project of the Land Stewardship Project and the Minnesota Department of Agriculture's Energy and Sustainable Agriculture Program, is $5 plus $2.90 shipping/handling from LSP, 14758 Ostlund Trail North, Marine on St. Croix, MN 55047; (612)433-2770.

The Industrialization of Agriculture: Policy, Research, and Education Needs — A Symposium is available from Tracy Irwin Hewitt, Council on Food, Agricultural, and Resource Economics (C-FARE), 9200 Edmonston Road, #117, Greenbelt, MD 20770; (301)441-8777.

1994 Membership Directory of the Carolina Farm Stewardship Association is $5 from CFSA, 115 West Main St., Carrboro, N.C. 27510; (919)968-1030.

MetroFarm: The Guide to Growing for Big Profit on a Small Parcel of Land, 576 pages, is $29.95 plus $4 shipping/handling from agAccess, 603 Fourth St., Davis, CA 95616; (916)756-7177.

Proceedings from the 1993 International Federation of Organic Agriculture Movements conference on Non-Chemical Weed Control are available from Association Colloque IFOAM, ENESAD-ENITA, BP 48, 21 802 Quetigny Cedex, France.

Best Management Practices, a 30-minute video, is $20, checks payable to Cashier, Dept. of Food and Agriculture, from Cashier, California Dept. of Food and Agriculture, P.O. Box 942872, Sacramento, CA 94271-2872.

Sell What You Sow, 304 pages, is $22.50 plus $2.50 shipping from New World Publishing, 3701 Clair Dr., Carmichael, CA 95608; (916)944-7932.

Plant and Soil Nematodes: Societal Impact and Focus for the Future is available from R.S. Hussey, Department of Plant Pathology, University of Georgia, Athens, GA 30602-7274; (706)542-1254.

Northeast Sustainable Apple Production Newsletter is inviting written contributions suitable for the newsletter, aimed at growers, marketers, researchers, and consultants involved in apple production and sales; contact Daniel R. Cooley, Editor, Dept. of Plant Pathology, Fernald Hall, University of Massachusetts, Amherst, MA 01003; fax, (413)545-2532.

Pesticides in the Home and Community: Health Risks and Policy Alternatives, 108 pages, a publication of the California Policy Seminar and a report of the Environmental Health Policy Program, is available from Environmental Health Policy Program, Center for Occupational and Environmental Health, School of Public Health, University of California, Berkeley, CA 94720; (510)642-8853.

International Workshop on Sustainable Land Management for the 21st Century, the proceedings of the June 20-26, 1993, workshop of the same name, is available from Cindy LaValley, International Workshop Organizing Committee, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta, Canada T1K3M4; (403)329-2244.

Profitable Ideas for the Small Farm, 16 pages, a reprint from *Growing for Market*, is $10 from Fairplain Publications, P.O. Box 3747, Lawrence, KS 66046; (913)841-2559; 12-issue subscriptions to *Growing for Market* are $26 a year.

Whole Farm Case Studies of Horticultural Crop Producers in the Maritime Pacific Northwest, SB 678, a report on a collaborative project of Oregon State University and Washington State University, is available at no charge from Publications Orders, Agricultural Communications, Oregon State University, Administrative Services A422, Corvallis, OR 97331-2119.

Beginning Farmer Sustainable Agriculture Project Interim Report, which summarizes the findings of a project cosponsored by the Center of Rural Affairs, University of Nebraska—Lincoln, and Nebraska Sustainable Agriculture Society, is $4 from Center for Rural Affairs, P.O. Box 736, Hartington, NE 68739; (402)254-6893; Nebraska residents add $.20 sales tax.

Worm Digest, a new quarterly newsletter about worms and worm composting, published by the Edible City Resource Center, is $4.50 a year from Worm Digest, Box 544, Eugene, OR 97440-9998.

Forage Legumes: Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch, Sainfoin and Alfalfa, 40 pages, #SB-5963-NR, is $5, payable to University of Minnesota, from Distribution Center, 20 Coffey Hall, University of Minnesota, St. Paul, MN 55108; (612)625-8173 for credit card orders; Minnesota residents add $.33 sales tax.

Participatory assistance: An alternative to transfer of technology for promoting change on farms

L.E. Lanyon

Abstract. *Participatory assistance (PA) is a proposed approach for promoting change that involves both the biophysical processes of farms and the management processes of farmers. It integrates external expertise, inputs, and expectations with the unique character of a particular farming system. It focuses on improving the processes of the farm and farmer rather than on the traditional interests of "outsiders" such as disciplinary researchers, industry sales people, government regulators, consumers, or environmental interest groups. As an alternative to transfer of technology, it promotes learning both by the farmer and by specialists from academia, industry, government, and the public. Participatory assistance can promote innovations in the operation of farms, in the conduct of research and education, in the development of products and services, in the formulation of policy, and in the involvement of the public in agriculture. The outcome is not assumed to be the adoption of the "best" technology, but may be found in the emerging properties that result from innovations. Assessing the improvement that follows each innovation will require clear specification of the relevant performance criteria, provision of appropriate technical support, and reinforcement by the appropriate incentives. Reconciling today's farming with water quality protection illustrates the potential of the PA approach.*

Key words: technology transfer, farm management, water quality

Introduction

Many recent changes on farms were promoted by agents of change through the transfer of technology (TOT) approach to farmers. This approach has been successful in the diffusion and adoption of externally developed innovations, especially such production-related advancements as fertilizers, pesticides, farm machinery, animal housing, and new germ plasm. However, as the consequences of recent changes in agriculture are recognized and new expectations established (Batie, 1988), the relevance of TOT, with its focus on adopting external factors of production, may be diminished (Schultz, 1964). Participatory assistance (PA) is proposed as an alternative to TOT for promoting change in agriculture. PA is different from participatory research (Gerber, 1992) in that it emphasizes participation in a total farmer/farm-centered process rather than farmers participating in a research activity that is the interest of disciplinary specialists.

After a brief comparison of PA and TOT, I describe the biophysical and management features of PA. Since it has been so widely used, TOT has many forms. However, the essence of TOT is presented as a benchmark for comparison. I will illustrate the PA approach with examples of managing nutrients to protect water quality on integrated crop and livestock farms.

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Participatory Assistance and Transfer of Technology

The contrast between several key features of PA and TOT is shown in Table 1. TOT promotes the adoption of a "best" practice, product or policy to achieve an "advantage." Often this advantage is specified by the technology innovator or the agency of change, rather than being based on improving a situation described by the farmer. Reliance on the authority of the agent of change to promote adoption through TOT is very different from the cooperative involvement with the farmer that characterizes the authentic participation of PA. TOT is a linear activity based on adoption, while PA is iterative and based on involvement. PA presents an opportunity to pursue learning by a series of experiences; TOT ignores this possibility through the linear transfer of prescriptions. TOT predicts the well-defined effects of specific practices, products or policies; PA focuses on measuring probabilistic performance. PA is more flexible and more evolutionary: it can anticipate and respond to the consequences of change, and is not constrained to a particular message. Unforeseen consequences of TOT are simply the next problem to be solved. PA is more compatible with the holistic nature of deci-

sion-making at the level of the farm system than is the reductionist paradigm of components associated with TOT. The scope of TOT is the known properties of the message being transferred, whereas PA can stimulate emergent features of farming systems based on creative innovations, including those of the farmer. These unanticipated features, which represent the essence of a systematic approach to change, are observed because of an incomplete initial specification, a new observational scale, or the irreducible nature of the whole to its parts (Allen and Starr, 1982). They are welcomed in PA but troublesome in TOT.

Biophysical Process

Since farming is both a biological and a physical activity, the essential biophysical process considered in PA is the movement of material to, from, and within a farm. This material movement is a human-scale, phenomenological, managed-system process. It is not the sum of individual "natural" or mechanistic processes for each farm component, such as the growth of individual crops or production by individual animals. Observation of material movements to and from fields, into and out of the livestock units, and to and from the farm itself can be effective in portraying particular farming systems, the influence of regional surroundings on farm opportunities through the connections across the farm boundaries, and the contribution of system components to the functioning of the whole farm (Allen and Starr, 1982; Bacon et al., 1990). PA does not rely solely on detailed information about particular components, but attempts to monitor the logistical processes that link the components.

Information about farm processes at this scale can connect farming activities with possible ecological consequences, since spatial and temporal dimensions of material flow are also essential dimensions of ecological activity. For example, the effects of farming practices on water quality can be estimated from the interactions of the farm material flow and the ecological processes within which the farm is embedded. The potential for nitrate leaching from farm fields is related to the balance of N supplied and N used based on farm material movement (Bacon et al., 1990; Pionke et al., 1991).

Each farm has particular patterns of material movement and relies on an assortment of off-farm technical inputs to generate a variety of outputs. Since World War II, changes in the surroundings of farms, specifically the availability of new production inputs and marketing opportunities, have created diverging paths of farm evolution within the set of all farms (Lobao, 1990; Lanyon, 1992). Before the recent proliferation of these technical factors, neighboring farms differed less than they do now, with their characteristics constrained primarily by local resources and culture (Schultz, 1964; Van Arsdall and Nelson, 1984; Lobao, 1990). These constraints have been relaxed through technological developments and availability of materials. Salamon (1985) described the distinctively different farming systems created by two neighboring ethnic groups in Illinois: one is based on animal agriculture, the other on cash crops. The cash crop farmers grow mainly corn (*Zea mays* L.) and soybeans (*Glycine max* L.). This cropping sequence emerged only since the 1940s because it depends on continuous inputs of nitrogen fertilizer and a market for soybeans, neither of which were well developed before World War II (Berlan et al., 1977). The animal agriculturalists rely heavily on dairy and other livestock for income and emphasize the contributions of farm labor and land. Thus, although the farms are located within 30 km of each other, farmers in each group now can combine a broad array of inputs and resources in ways that previously were not possible.

Emphasis on material movement in the managed pathways to, from and within a farm distinguishes PA from a TOT approach to farm change. The description of the biophysical process is not merely an inventory of isolated components or a composite farm from a cross-sectional farm survey. A further defining feature of a complex system such as a farm is its connection to its surroundings (Ulanowicz, 1986), for example, through purchased inputs such as feeds and fertilizers and through marketing. More opportunities for change in farm operation can be identified using the biophysical connections among farm components than through approaches that focus only on specific, isolated components and their related technologies. For instance, a technology-based approach to nutrient pollution from nonpoint sources might look only at field management, although changes in animal management might be an alternative way to reduce the pollution potential on a particular farm. Animal rations could be balanced more closely using traditional techniques (Pell, 1992), or enzymes could be added to enhance the efficiency of phosphorus utilization (Cromwell et al., 1993). These techniques could reduce the purchased inputs that contribute to the nutrient load that must be managed.

Management Process

The basic management process in PA is a sequence of activities involving planning, implementation, and control (Fig. 1). Assessing implementation and selecting options for the next iteration of the management process are key activities of the control function. Decisions within this framework determine the operation and fate of the managed system. Several levels of management are commonly identified (Davis and Olson, 1985), each representing a different balance of planning, implementation and control, and each requiring different information (Table 2).

Tactical management is planning and controlling business operations within a period of one to five years (Table 2). This is a particularly effective management level for facilitating farm change through PA. The information needs and tasks of the tactical manager generally correspond to the technical information available from external sources. For instance, technical information concerning animal manures as sources of nutrients for crops can be incorporated into a plan covering the timing and rate of manure application, the amount and sources of additional nutrients required, and the evaluation of crop nutrient status to insure that crop requirements are met. This plan will be based on considerations such as the results of manure testing, soil test levels, and the crops' potential to use nutrients through the entire crop rotation.

Strategic management deals with planning the future success of the organization, and is the responsibility of the organization's top management. Strategic management decisions integrate information from a wide variety of technical and non-technical sources, some objective and some very subjective. Strategic decisions about organizational goals rely heavily on these managers' judgments concerning external conditions and prospects. Future business

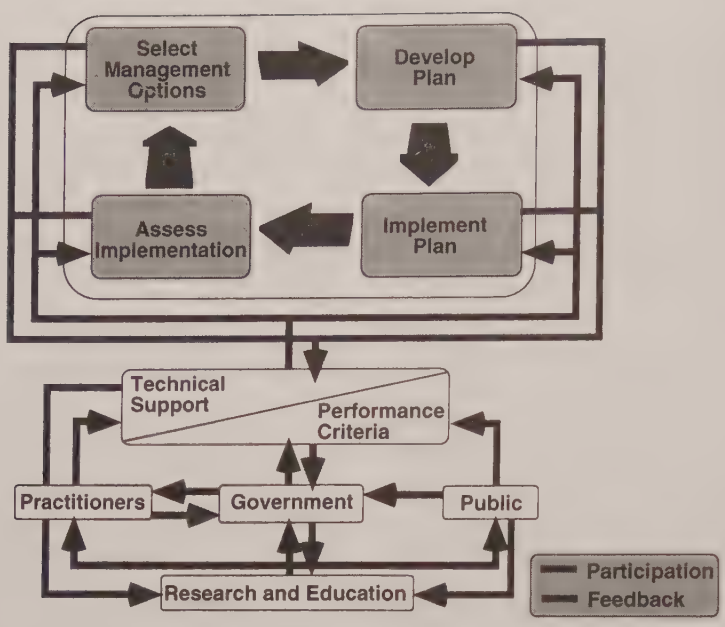

Fig. 1. The process of participatory assistance based on participation and feedback. The diagram illustrates the farm manager's activities, the participation of technical support practitioners, the role of government and the public in specifying performance criteria, and the linkage of research and extension efforts to the other participants.

Table 1. Contrasting features of transfer of technology (TOT) and participatory assistance (PA).

	TOT	PA
Goal of change	adopt ideal	improvement
Approach by agents of change	authoritarian transfer	authentic participation
Outcome of change	confer "advantage"	promote satisfaction
Basis for change	practice-based	performance-based
Sequence in process of change	linear	iterative
Perspective on the future	predict	anticipate/respond
Anticipated organizational properties	known	emergent
Consequences of change	assumed	measured

Table 2. Representative features of different levels of management.

	Level of Management		
	Strategic	**Tactical**[1]	**Operational**
Management action period	>5 years	1 to 5 years	<1 year
Responsible staff	top managers	⟷	supervisors
Outcomes of decisions	goals	⟷	tasks
Emphasis in organization	holistic	⟷	component
Accuracy of information	low	⟷	high
Nature of information	subjective	⟷	objective
Source of information	surroundings	⟷	organization

[1] Tactical management is intermediate between strategic and operational on the management continuum. The arrows represent the continuous change from one level to the next, and highlight the flexibility in management at that level.

conditions and prospective opportunities are emphasized rather than highly accurate internal information about the organization. An example of a strategic goal for a farm might be to balance enhanced farm production and reduced groundwater pollution.

Strategic management decisions depend in part on information from the tactical level, where PA is most robust. For instance, a dairy farmer might consider adding an intensive hog or poultry enterprise to a dairy farm so that a son can become part of the farm operation. This decision could be influenced by the current nutrient status of the farm, impending regulations, and the options for manure management. If the dairy enterprise currently relies heavily on purchased feeds and if soil fertility is high, then a broiler enterprise might be more appropriate than a confinement hog facility. The broiler enterprise will generate a relatively dry manure that can be exported from the farm more easily than the liquid manure that is characteristic of current hog facilities. Information about the farm's nutrient balance, soil test results, and modern animal housing systems would not be the entire basis of the decision, but it would contribute. A hog specialist or a representative of the hog industry will attempt to accommodate environmental considerations in the operations of a new hog facility, but neither is likely to suggest starting a broiler enterprise instead. In PA, however, the choices among various animal enterprises are just as likely to be considered as the production techniques within a particular enterprise.

Operational management involves specific activities to implement the tactical plans that will accomplish the strategic goals. Detailed, organization-specific information is the key to operational success. Operational managers are responsible for organizing, executing, and recording the many transactions of the managed system. To protect groundwater from excessive nitrate leaching, operational decisions would need to control all forms of N supplied to specific fields and to insure that crop yield goals are achieved. Examples of specific operational management activities include spreading a specified amount of animal manure on a particular day on a given field, controlling a flush of weeds that might re-

duce crop yields, and harvesting the crop at the optimal time, depending on crop maturity, field conditions, and availability of labor and machinery.

Operational management decisions, such as deciding which tractor and manure spreader are to be used by which operator to apply manure on a particular field on a given day, are generally so farm-specific that PA will not provide adequate technical assistance at this level. As an outgrowth of the kind of research in which all factors except the treatment variable are controlled, the scientific basis of PA is too general to meet specific operational needs. These decisions depend heavily on judgment, as in strategic management. However, the operational manager must be familiar with the organization's capabilities, not just with its surroundings. Richards (1985) attributes the unique power of science to its independence of the specifics of time, place or special interests. But he also cites this as a limitation in dealing with many environmental problems that require ecologically and organizationally specific responses.

Even with its limitations, PA can transcend the confines of each management level more effectively than alternative methods of promoting change, such as TOT. In contrast to PA, which looks for opportunities for improvement throughout the system, TOT simply offers specific technologies and requires that they be used in the "right" way. For example, in practice/product-based TOT, the message might be that sidedressing corn with N is more efficient than preplant applications and, therefore, reduces groundwater pollution. However, this message does not consider whether timing of N fertilizer application is the most critical factor influencing the N pollution from a particular farm, or how sidedressing N fertilizer relates to other farm practices or goals. On a particular field, the N balance may be controlled not by the N fertilizer application technique, but by other production factors that determine crop yield, such as weed control. The holistic perspective of PA can more easily identify the specific limitations on particular farms than TOT can. Also, many problems in protecting water quality result from strategic rather than operational characteristics, such as high volume, low cost livestock or poultry production that relies on external feeds rather than farm-produced crops (Westphal et al., 1989), or from dependence on government programs (Foltz et al., 1991). Refining operational activities within these strategies may not address adequately the water quality consequences of particular ways of farming (Isermann, 1990). PA can support the modification of production strategies and help in their implementation.

Technical Support and Performance Criteria

Technical support for farm management can be provided in PA for each management activity (Fig. 1) and can contribute in different ways to each management level. Techniques are available or could be developed to help managers create tactical nutrient management plans to maintain water quality (Beegle and Durst, 1988), to track the implementation of nutrient management plans through recordkeeping (Lanyon and Meij, 1992), and to perform nutrient balance assessments (Lanyon and Schlauder, 1988).

Explicit performance criteria provide the benchmarks for management control in PA (Fig. 1). For instance, defining balanced nutrient use and establishing it as an indicator of satisfactory performance are essential features of PA, whereas nutrient management TOT might simply emphasize the soil and manure testing or manure application techniques.

PA can contribute quantitative insights to operational management if the performance criteria are appropriate. For instance, timely information on the agreement between planned applications of manure and the actual applications can be used by the operations manager to formulate and implement responses to actual farm situations. If the actual manure applications to particular fields were less than planned, closer monitoring of soil and plant N status may be required than if the planned and actual applications agreed (Meij et al., 1992).

Since PA focuses on the farm process and farmer management, the farmer's expectations and expertise routinely will be included in the approach. Unlike other modes of promoting change, PA will integrate external criteria with the continuing guidance of the farmer. TOT transfers information about farm "pieces" from the surroundings to the farm. The technology is adopted by those farmers whose interests are consonant with its characteristics. Farmers may adopt a practice or product through TOT for reasons entirely different from what the promoters of the technology assume. Consequently, implementation of technology may not meet the external expectations. For example, manure storage facilities are generally promoted as part of "good" nutrient management to protect environmental quality because they limit the need to apply manure daily. However, some farmers may adopt them simply because storage of manure is more convenient than daily hauling; any changes that may occur in nutrient utilization by crops because of manure storage will be secondary.

Transfer of technology generally assumes that the farm manager will "adopt" the recommended practice because it is in everyone's best interest. Limits to voluntary changes in farm operations can arise either from inadequate technical support or from the incompatibility of the innovation with the management of the farm operation (Chambers, 1989). Since TOT does not differentiate between technical support to the farmer and the character of the innovation, reasons for "inadequate" adoption cannot be differentiated. Best management practices for reducing pollution from nonpoint sources have had a limited effect because they tend to meet the interests of environmental groups rather than farmers (Logan, 1990). Improving only technical support for these practices may not enhance their adoption. Napier and Camboni (1993) observed that farmers' concern for the environment or access to information are not major barriers to using potentially polluting practices, nor are they related to adoption of specific conservation practices. By maintaining the difference between technical support and performance criteria, PA can promote learning about the different factors that control change. The consequences of prospective changes in technical support could be differentiated from those of possible changes in performance criteria. Requiring clear statements of performance criteria that are distinguished from technical support can establish the expectations for farm operations, rather than prescribing farming methods to achieve "good practice." Farm managers and their technical advisers then would be able to innovate within the context of an individual farm to develop unique means of achieving the expectations. Instead of short lists of standard best management practices that farmers must adopt to comply with soci-

ety's expectations, farmers could generate an unending array of unique solutions that achieve the performance criteria.

External participants in PA can accumulate experience through feedback from each management activity (Fig. 1), which offers them a substantive learning opportunity. In contrast, perceptions of farm operations and farmers that sometimes govern TOT or that result from cross-sectional farmer surveys may not adequately reflect the rational basis of farm management decisions and may not identify current impediments to changes in management. TOT tends to be immersed in the details of the innovation and the goals of the organization generating the innovation (Chambers, 1983). Surveys of farmers generally miss the essential connections among components and actions that define unique complex systems such as individual farms. Consequently, technology-based learning or learning from farmer surveys can limit the opportunities for change compared with PA because each excludes essential features of the system to be changed.

Feedback from particular management activities to outsiders through PA may increase the opportunities for change based on experiences that attempt to integrate the goals of the farm manager and the performance expectations of the outsiders. This feedback can help reduce misunderstandings of farm operations among interested groups or stakeholders. When considering the effect of farm operations on shared resources such as surface or groundwater, improved understanding based on effective two-way communications can insure the behavior agreed upon by the affected parties (Runge, 1981). In the example of manure storage, a farmer who adopts the storage for convenience will not necessarily manage it to protect the environment from pollution. The TOT approach would view any discrepancy between the assumed improvement in nutrient utilization and actual performance as a problem of the farmer, not of the process used to promote change.

Technical support in PA would primarily be the responsibility of practitioners who are trained to establish the essential processes of a farming system and to facilitate on-farm management activities (Fig. 1). These practitioners would provide the expertise to identify and conduct essential activities for planning, implementation and control. The practitioners' way of knowing would equip them to measure precisely and to look closely at the whole range of relevant farm activities (Chambers, 1983). Their technical skill could complement the indigenous knowledge of the farmer, which is generally stronger in locally relevant observations (Chambers, 1989). PA would meld the universal with the particular.

External performance criteria can be generated by many different participants, such as government agencies or the public. Current concerns for the environmental consequences of agricultural production can be the stimulus for new performance criteria. Boehlje and Eidman (1984) have noted that recognized standards for controlling operations are essential to management success; similarly, Lewin (1952) identified standards of achievement as essential for learning. Without standards, there is nothing against which to compare the farm's performance, and no guidance regarding what information should be collected to describe that performance. Setting performance criteria requires defining the expectations of farm management, not establishing the "best" technique. Responding to management control as an element of PA permits the farmer to achieve the specified performance level in a variety of ways. In contrast, TOT would promote the adoption of particular practices, predicting that performance would be acceptable. Failures of TOT often are viewed as breakdowns in promoting adoption of practices rather than consequences of inappropriate technical support or irrelevant performance criteria.

Research and Education

Research outcomes and educational programs (Fig. 1), such as those associated with the land-grant universities or private industry, can be part of PA in various ways, with various clienteles. Interactions with practitioners will provide opportunities to enhance the technical aspects of farm management. PA also will promote feedback from practitioners about farmers' needs for technical support and the performance of actual farm management units. Feedback and opportunities for participation will encourage research dealing with farm management processes besides traditional disciplinary research on farming system components. Busch and Lacy (1983) found that many researchers chose to explore what interests them, with their choices often a reflection of how they were trained or the result of calls for research from funding agencies. Since there are few opportunities to study the organization of entire farms, research often is focused on narrowly defined problems specified by other scientists with the same disciplinary interests. Specific research challenges may emerge from PA to meet the needs of the practitioners to collect information about processes and to do process-based research (Rogers, 1983).

Process-based research focuses on time-ordered sequences of events involving the farm manager, such as those associated with innovation and learning. In contrast, the prevalent mode of "variance-based" research attempts to define the proportion of experimental variation that can be attributed to specific treatments. It is not sensitive to time and history, unlike the decisions of most farm managers, who are the presumed beneficiaries of agricultural research (Lanyon, 1989). Richards (1989) compares farm management to performance art in its dynamic interaction between the manager and conditions. Normal disciplinary science often is insensitive to the context of technologies. All factors except the treatment variable must be held constant. However, Lorenz (1963) observed that the unfolding of even a simple set of mathematical equations over time is very sensitive to the initial conditions. If a farm process is viewed as an unending sequence of particular decisions, the utility of universal recommendations resulting from variance-based evaluations will be limited. If PA enriches the experiences of researchers and the participants from funding groups, it may lead to increased interest in a different group of process problems.

PA would promote learning by farm managers about their particular management units. This learning could include new facts about farm components, the acquisition of new skills, or the emergence of new insights. TOT delivers facts about practices or products, but it is less likely than PA to stimulate strategic insights, especially those based on the site-specificity of a particular farm. Also, PA would pro-

vide the experience and information that outsiders can use to learn about specific management units.

Management theorists often use the "Johari window" (Fig. 2) to explain learning frontiers and interactions in learning (Hersey and Blanchard, 1982). The horizontal dimension of the window is information known to self, such as the individual farmer. The other dimension is information that is known to others, such as those outside the farm. Significant learning frontiers separate the blind and private sectors from the public information. The region of mutual awareness can be expanded by feedback from the farm manager to outside participants. TOT assumes a linear process of learning in the region unknown to self but known to others. The adoption sequence from awareness through full-scale adoption assumes that the answer has been provided by the agents of change, so that the challenge to the farmer is to determine if it "fits" (Rogers, 1983). PA accommodates learning on both frontiers of the Johari window. It does not presume that change in complex, evolving farming systems must overcome ignorance on the part of the managers.

Learning through participation could be sensitive to differences in cognitive style among the learners. Current theories on the individuality of the learning process are illustrated by "field theory" (Witkin et al., 1977). Learners who are "field dependent" perceive patterns as wholes, and focus less on the elements of a situation. They learn by observing. In contrast, "field independent" learners are more analytical and abstract, and more comfortable with the details of a situation. The learning styles of researchers influence the development and delivery of TOT programs, while the learning styles of farmers influence the adoption of technology. PA would be sensitive to the differences in approaches to learning by farmers and outsiders, and to the possibility of a range of styles within the farmer group. PA could stimulate diverse ways of packaging external information and could equip participants with technical support techniques that complement various ways of knowing about farming systems.

Since many technical practitioners in agriculture have been trained as disciplinary specialists, implementing PA would require training programs in the management and process control of farming systems. This education would emphasize new skills and insights on the farm system level, rather than more exhaustive disciplinary information. Practitioners would be empowered to participate in the actual farm processes, conduct thematic and holistic investigations of their operations, confront situations that limit farm performance, and with the farmers transform the farms (Freire, 1970). Crafting and participating in training programs with the practitioners would also enhance the opportunities for educators to perceive needs as new situations are encountered by practitioners in the evolving transformation of agriculture.

Policies would be formulated in different ways, too. Instead of simply transferring technology to farmers who are perceived as mismanaging resources and blind to the benefits of change, the basis for formulating policy would be the rational elements of management decisions in their specific, complex context. Learning would expand the public frontier into the private space (Fig. 2). Such revised policies could be based on performance criteria, not on rigidly defined practices (Porter, 1991). Assessing improvements in performance would require that we specify clearly the relevant performance criteria and provide the appropriate technical support. Instead of investing effort in technical prescriptions, we could invest effort in formulating performance standards, techniques for ascertaining how well the standards are being met, and appropriate incentives for farmers to meet the expectations.

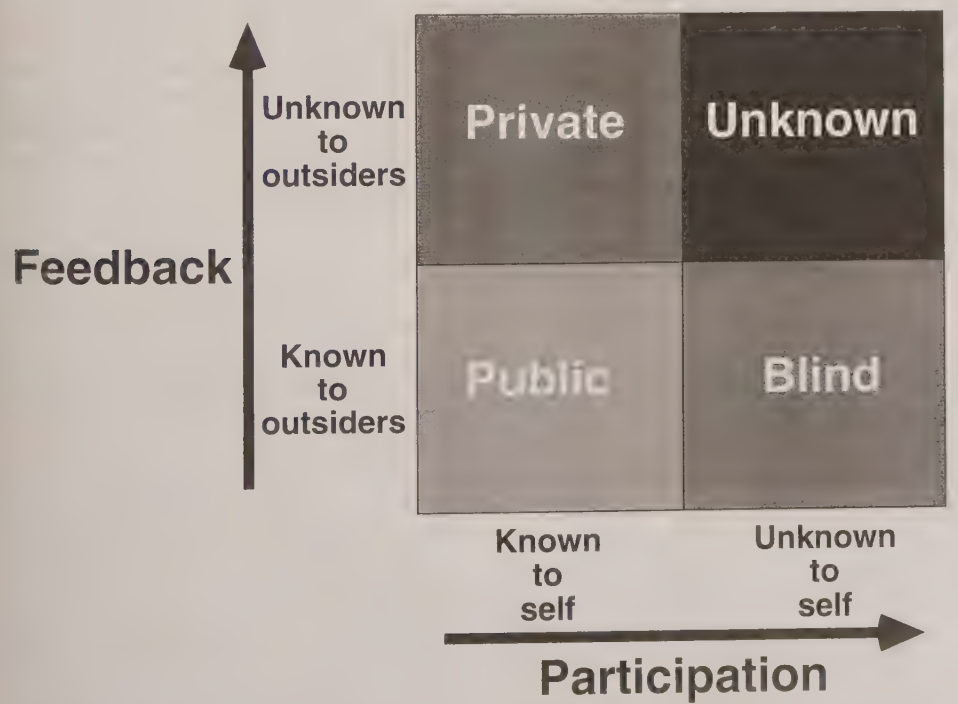

Fig. 2. An adaptation of the Johari window to illustrate the participation and feedback linkages of participatory assistance. Farmers are represented as "self" and the external participants as "outsiders" in this adaptation.

References

1. Allen, T.F.H., and T.B. Starr. 1982. Hierarchy. Univ. of Chicago Press, Chicago, Illinois.
2. Bacon, S.C., L.E. Lanyon, and R.M. Schlauder, Jr. 1990. Plant nutrient flow in the managed pathways of an intensive dairy farm. Agronomy J. 82:755-761.
3. Batie, S. 1988. Agriculture as the problem: New agendas and new opportunities. Southern J. Agric. Economics 20:1-11.
4. Beegle, D.B., and P.T. Durst. 1988. Farm nutrient management worksheet. ECS No. AAG-01013, v2. Dept. of Agronomy, The Pennsylvania State Univ., University Park.

5. Berlan, J-P., J-P. Bertrand, and L. Lebas. 1977. The growth of the American "soybean complex." European Review of Agric. Economics 4:395-416.
6. Boehlje, M.D., and V.R. Eidman. 1984. Farm Management. John Wiley and Sons, New York, N.Y.
7. Busch, L., and W.B. Lacy. 1983. Science, Agriculture, and the Politics of Research. Westview Press, Boulder, Colorado.
8. Chambers, R. 1983. Rural Development. Longman Scientific and Technical, Essex, Great Britain.
9. Chambers, R. 1989. Reversals, institutions and change. In R. Chambers, A. Pacey, and L.A. Thrupp (eds). Farmers First. The Bootstrap Press, New York, N.Y. pp. 181-195.
10. Cromwell, G.L., T.S. Stahly, R.D. Coffey, H.J. Monegue, and J.H. Randolph. 1993. Efficacy of phytase in improving the bioavailability of phosphorus in soybean meal and corn-soybean meal diets for pigs. J. Animal Sci. 71:1831-1840.
11. Davis, G.B., and M.H. Olson. 1985. Management Information Systems. McGraw-Hill Book Co., New York, N.Y.
12. Foltz, J.C., M.A. Martin, and J. Lowenberg-Deboer. 1991. Inclusion of alfalfa (*Medicago sativa* L.) in crop rotations in the eastern Corn Belt: Some environmental and economic implications. J. Sustainable Agric. 2:117-133.
13. Freire, P. 1970. Pedagogy of the Oppressed. Reprinted 1986. Continuum Publishing Corp., New York, N.Y.
14. Gerber, J.M. 1992. Farmer participation in research: A model for adaptive research and education. Amer. J. Alternative Agric. 7:118-121.
15. Hersey, P., and K.H. Blanchard. 1982. Management of Organizational Behavior. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
16. Isermann, K. 1990. Share of agriculture in nitrogen and phosphorus emissions into the surface waters of Western Europe against the background of their eutrophication. Fertilizer Research 26:253-269.
17. Lanyon, L.E. 1989. Combining "art" and science in nutrient management. Proc. Dairy Manure Management Symposium, February 22-24, 1989, Syracuse, NY. NRAES-31. Northeast Regional Agricultural Engineering Service, Cornell Univ., Ithaca, N.Y. pp. 69-78.
18. Lanyon, L.E. 1992. Can a modern dairy farm be sustained? J. Sustainable Agric. 2:83-99.
19. Lanyon, L.E., and H.K. Meij. 1992. FINFO: Field and farm technical information management program. J. Production Agric. 5:88-94.
20. Lanyon, L.E., and R.M. Schlauder, Jr. 1988. Nutrient management assessment worksheets. Version 2.0L for Lotus 1-2-3. Agronomy Series No. 102. Dept. of Agronomy, The Pennsylvania State Univ., University Park.
21. Lewin, K. 1952. Group decision and social change. In G.E. Swanson, T.M. Newcomb, and E.L. Hartley (eds). Readings in Social Psychology. Holt and Co., New York, N.Y. pp. 459-491.
22. Lobao, L.M. 1990. Locality and Inequality. State Univ. Press of New York, Albany.
23. Logan, T.J. 1990. Agricultural best management practices and groundwater protection. J. Soil and Water Conservation 45:201-206.
24. Lorenz, E. 1963. Deterministic nonperiodic flow. J. Atmospheric Sci. 20:130-141.
25. Meij, H.K., L.E. Lanyon, and A.D. McNall. 1992. Application of thematic mapping in an agricultural information management program. In D.G. Watson, F.S. Zazueta, and A.B. Bottcher (eds). Computers in Agricultural Extension Programs. Proc. 4th International Conf., January 28-31, 1992, Orlando, Florida. Amer. Soc. Agric. Engineers, St. Joseph, Michigan. pp. 7-12.
26. Napier, T.L., and S.M. Camboni. 1993. Use of conventional and conservation practices among farmers in the Scioto River basin of Ohio. J. Soil and Water Conservation 48:231-237.
27. Pell, A.N. 1992. Does ration balancing affect nutrient management? Proc. Cornell Nutrition Conf. October 13-15, 1992, Rochester, N.Y. Dept. of Animal Science, Cornell Univ., Ithaca, N.Y. pp. 23-31.
28. Pionke, H.B., J.B. Urban, W.J. Gburek, A.S. Rogowski, and R.R. Schnabel. 1991. Sampling groundwater in a northeastern U. S. watershed. In R.G. Nash and A.R. Leslie (eds). Groundwater Residue Sampling Design. ACS Symposium Series 465. Amer. Chemical Soc., Washington, D.C. pp. 222-241.
29. Porter, M.E. 1991. America's green strategy. Scientific American 266:168.
30. Richards, P. 1985. Indigenous Agricultural Revolution. Westview Press, Boulder, Colorado.
31. Richards, P. 1989. Agriculture as performance. In R. Chambers, A. Pacey, and L.A. Thrupp (eds). Farmers First. The Bootstrap Press, New York, N.Y. pp. 39-43.
32. Rogers, E.M. 1983. Diffusion of Innovations. 3rd ed. The Free Press, New York, N.Y.
33. Runge, C.F. 1981. Common property externalities: Isolation, assurance, and resource depletion in a traditional grazing context. Amer. J. Agric. Economics 63:595-606.
34. Salamon, S. 1985. Ethnic communities and the structure of agriculture. Rural Sociology 50:323-240.
35. Schultz, T.W. 1964. Transforming Traditional Agriculture. The Univ. of Chicago Press, Chicago, Illinois.
36. Ulanowicz, R.E. 1986. Growth and Development. Springer-Verlag, New York, N.Y.
37. Van Arsdall, R.N., and K.E. Nelson. 1984. The U.S. Hog Industry. Agric. Economics Report No. 511. Economic Research Service, U.S. Dept. of Agric., Washington, D.C.
38. Westphal, P.J., L.E. Lanyon, and E.J. Partenheimer. 1989. Plant nutrient management strategy implications for optimal herd size and performance of a simulated dairy farm. Agric. Systems 31:381-394.
39. Witkin, H.A., C.A. Moore, D.R. Goodenough, and P.W. Cox. 1977. Field-dependent and field-independent cognitive styles and their educational implications. Review of Educational Research 47:1-64.

Letters To The Editor Invited

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BOOK REVIEWS

The Biodiversity of Microorganisms and Invertebrates: Its Role in Sustainable Agriculture. Edited by D.L. Hawksworth. 1991. CAB International. Distributed by the University of Arizona Press, 1230 North Park Avenue, Suite 102, Tucson, AZ 85719-4140. xx+302 pp. $76.00, hardcover.

This book is the proceedings of the *First Workshop on the Ecological Foundations of Sustainable Agriculture*, held in London in July 1990. The rationale for the workshop was the recognition that the greatest pool of genetic diversity is found in invertebrates and microorganisms, organisms that play a vital role in maintaining and enhancing soil fertility and hence in making agriculture sustainable. The major question was whether enough was known about the diversity and genetic resource base of these organisms to make wiser agricultural development decisions that include adequate consideration of sustainability. The short answer is "maybe."

Four main subjects are covered: the importance of invertebrates and microorganisms as components of biodiversity; the importance of biodiversity in sustaining soil productivity; the importance of biodiversity to pest occurrence and management; and biotechnology and biodiversity among invertebrates and microorganisms. The statements of conclusions and findings are particularly worth reading because they present succinct questions and challenges not only to biological and agricultural researchers, but also to economists, sociologists and policymakers.

In the first section, we are reminded of the significant but often overlooked role that microorganisms and invertebrates play in biological processes. These organisms ensure that we survive the "death, dung, and detritus" of our own and other species. We do not know just how much we don't know regarding microbial and invertebrate diversity, but we need to set priorities for what should be done and by whom. Completing an accurate inventory of the world's microorganisms and invertebrates would take over eight centuries at the current rate of progress. Obviously, decisions need to be made with much less than full information. There was support among the participants for dual approaches of *in situ* conservation and conservation in collections. Many of the participants focused on groups that are of functional importance in ecosystems ("keystone species") or are most likely to be of value to humans. This anthropogenic view, in my opinion, causes problems in making accurate decisions. For example, thermophiles might not be included by some as being of significance, yet an enzyme derived from a thermophile is essential to the molecular biology and biotechnology industry (Taq polymerase).

The participants lamented the declining interest in taxonomy among scientists, funding agencies, and industry. Paradoxically, although the world is now recognizing the significance of biodiversity, few people are interested in or supportive of classification of organisms (although molecular biosystematics is receiving reasonable attention). Yet successful applications in agriculture, medicine and industry, and even information technology in communications, require taxonomic knowledge and analysis. One possibility is for this to be handled by international centers for identification services, such as CAB International, a sponsor of the workshop.

Fundamental problems still exist in defining biodiversity, adopting standards for sampling methods to facilitate comparisons, and determining the role of culture collections. Not surprisingly, there are conflicting estimates of the number of species and different ideas about what constitutes a species. Although classes with smaller body size are known to contain a progressively greater number of species, how well this relationship holds for microorganisms is unknown because most are undescribed or cannot yet be cultured. Culture collections clearly help preserve genetic diversity, but more than one participant suggested that priorities need to be set because not everything can be maintained in this way or in its original form. A minority view that needs further examination is that some gene banks have too many samples.

A convincing case, not surprisingly, was made for the importance of microorganisms and invertebrates for enhancing and sustaining soil productivity. Enhancing the activity of soil biota is usually more effective in mitigating soil erosion than engineering practices for water management. But not all soil biota are equal. For example, while most earthworm activity is considered beneficial, some species harm soil structure. Practices that enhance soil and water resources and promote diversity of soil biota are described.

The book also discusses introductions of indigenous and foreign organisms for practices such as nitrogen fixation and biological control. For example, cyanobacteria inoculation in rice fields should be reconsidered because of the failure of foreign strains to become established. Greater use of indigenous strains might be preferable.

It is axiomatic that biodiversity is a desirable characteristic that is greatest in natural and sustainable ecosystems. But data are presented that this is not always the case. Thus, in rice fields cultivated for centuries, high biodiversity as such does not imply stability or low pressure from insect pests.

Little information beyond conjecture is presented on the potential effects of biotechnology on diversity, both beneficial and harmful. I believe its overall effects will be neutral; microorganisms and invertebrates can adapt genetically to most manipulations of plants, animals and themselves. Producing and maintaining such genetically modified organisms has great technical difficulties and may be either unacceptable to the public or uneconomical.

Workshop participants pointed out that there is good biological understanding of what can and should be done to promote a sustainable agriculture and environment.

However, economists and policymakers seldom put biology into their calculations of measurable inputs or outputs.

Throughout the book, many needs related to biodiversity are presented. For example, there is still "no predictive theory that enables us to determine what elements of biodiversity should be retained, added, or eliminated to enhance natural pest control." Inputs into agriculture are needed for output, but seldom are inputs measured in terms of energy. The quantitative and qualitative dimensions of diversity elude us. Conservation of habitats is needed, but there is no agreement on what to conserve and how to conserve them. The challenge is presented to develop "green" technology and public policies to promote sustainable agriculture.

The book has few errors and is well indexed, and the tables, figures, and graphs are well done. It has several general discussion questions and answers, and offers varying points of view to supplement individual presentations.

The book brings together many perspectives on biodiversity, especially in the temperate and tropical zones that feed and clothe the world. I recommend it to economists and policymakers because of its clear and concise style and its generally balanced remarks. The summary by the chairman, M.S. Swaminathan, is worth the price of the book. The book's ecological perspective can be appreciated by anyone interested in the role of microorganisms and invertebrates in agriculture and the environment.

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Food for the Future: Conditions and Contradictions of Sustainability. Edited by Patricia Allen. 1993. John Wiley & Sons, 605 Third Ave., New York, NY 10158. $39.95, paper. xiv+318 pp.

Food for the Future is a powerful and lively critique of sustainable agriculture. In this collection of papers, fifteen contributors delve into some of the most fundamental problems and assumptions about the meaning of sustainable agriculture and its future. The book came out of a meeting organized by Patricia Allen at the University of California at Santa Cruz, where the authors discussed many of the ideas they developed for the book. However, it is more than a conference proceedings: the careful selection of participants, their interaction on the book's topics and judicious editing resulted in unusually strong coherence for a collection of papers.

Several major themes run through this book: the need to broaden sustainable agriculture to encompass more aspects of the food system than just food production; the conflict between sustaining the benefits of agriculture for those who already reap them versus securing benefits for a broader population; and the more general need to include social issues in sustainable agriculture. Supporting themes are the evaluation of political actions and systems needed to broaden the scope of sustainable agriculture to include social justice issues; historical, social and political reasons that sustainable agriculture is narrowly construed at present; and the global implications of a broad definition of sustainable agriculture that would encompass social equity and healthy food along with farm profitability and environmental quality.

Several papers stand out for me as being exceptionally thoughtful and well-organized. Frederick Buttel analyzes sustainable agriculture as a scientific knowledge claim and symbol of a social movement, thus providing insights into its development and limitations. Patricia Allen and Carolyn Sachs discuss the basic contradictions of sustainable agriculture and the issues on which it is silent, and argue for a more equitable distribution of its benefits and inclusion of neglected issues. Michael Redclift's analysis of sustainable development and its implementation reveals many analogies with sustainable agriculture and political strategies for making it possible. Harriet Friedmann describes the need to re-embed the global food economy in regional economies and social life to ensure that sustainable agriculture is compatible with each society's needs, rather than simply incorporating the most cost-effective or efficient technologies. Katherine Clancy contributed a scholarly historical analysis of the lack of connections among food consumption, domestic hunger, and sustainable agriculture, outlining why closer connections are needed and precisely what they would require. Garth Youngberg, Neill Schaller and Kathleen Merrigan offer a succinct history of sustainable agriculture and analyze the influences of policy and public pressure.

Almost every paper in this book has thought-provoking arguments, although most made points with which I disagreed. One recurrent problem is the use of language and assumptions that may not be clear to many readers despite attempts by several authors to clarify their terms for the general reader. Another is a somewhat simplistic linkage of environmental and social degradation or improvement (with Lori Ann Thrupp's "political ecology" analysis of rural development in Latin America, in contrast, illustrating with cogent and concrete examples how the environmental and the social are linked). The discussions of the global implications of sustainable agriculture generally are abstract and of questionable usefulness. A few chapters include "wish lists" of changes in research or policy without substantive analysis of what is needed to implement these recommendations.

However, these minor shortcomings are outweighed by the significant strengths of the book as a whole. The book is very valuable in the way it pinpoints controversies and stimulates thought. The authors successfully identify major conflicts and contradictions in sustainable agriculture and analyze them with depth and vision. I would recommend this book widely to agricultural scientists, students, policy makers and educators as a beginning point for discussions of the kind of agriculture we as a society want to create and how we will build it.

Molly D. Anderson, Assistant Professor, School of Nutrition, Tufts University, Medford, MA 02155.

Guide for authors

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Units

Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

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The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

Key words

Provide subject matter key words suitable for use in scientific indexing.

Reference list

When citing material that has been covered in more than one format, such as the typescript of a conference presentation and a journal article, preference should be given to the version that is most readily available, and that is likely to remain so. Generally this means standard publication channels, such as books, journals, and regular government report series. Unpublished or informally-published material should be cited only when no alternative form exists.

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

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Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

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The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

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A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

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